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Energy Conservation and House Basements

A RESEARCH REPORT

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A Review of the Effects of Energy Conservation
Measures on Low-Rise Residential Basements

Sponsored by the
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Energy Consultants
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ABSTRACT/RESUME

This report is the end product of a state-of-the-art study on the effects of energy conservation measures on basements in low-rise residences. The report reviews the various types of basement construction, together with their associated structural problems. There is also a review of the various soil and water mechanisms that can lead to structural damage of basements. The options of interior and exterior insulation are discussed for various basement conditions. The report concludes with a general review of the areas that require further study and includes an annotated bibliography of 55 cited references.

* * *

Le présent rapport est le résultat d'une étude effectuée à l'aide de techniques modernes qui a porté sur l'incidence des mesures d'économies d'énergie sur les sous-sols de résidences de faible hauteur. Y sont examinés les divers types de construction de sous-sols et des eaux qui peuvent causer des dommages structuraux aux sous-sols. Des options possibles d'isolation intérieure et extérieure y sont passées en revue en fonction des diverses conditions propres aux sous-sols. Enfin, les auteurs concluent en faisant une revue générale des points qui devraient faire l'objet d'une étude plus poussée, et une bibliographie annotée de 55 sources citées est inclue dans leur rapport.

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About 90% of low-rise residential buildings in Canada have a full basement - poured concrete or block wall or stone wall. These are rarely insulated and are responsible for a considerable proportion of the heat loss from the building. Provided that no major structural changes are required, the thermal upgrading of basements can be one of the most cost effective ways of conserving energy, and therefore the technology of basement retrofit is an important one in the field of energy conservation.

Three main problems are encountered when devising techniques for retrofitting basements. The first relates to the existing condition of the basements themselves: basements are often the worst part of the house from a structural point of view and their condition can easily be worsened by improper retrofit techniques. Secondly, basements present a wide range of conditions, including constructional details, accessibility, soil problems, level of deterioration and extent of previous development. In this situation it is better to treat each basement on its own merits than to adopt a fixed retrofit strategy. Thirdly, the techniques of basement retrofit have been applied only within the last five years or so. Accordingly, there are few documented examples of basement retrofit and even these have not been around long enough to permit an evaluation of long-term effects.

This report is the first step in a planned R&D thrust on basement retrofit technology. Its purpose was to review the state of the art in 1982, as a basis for determining future R&D strategies. The review is justifiably biased towards breadth rather than depth, and should be read as an overview of the subject rather than as a detailed technical dissertation. In some areas the report is not as comprehensive as it might be, and in others the interpretations may soon be modified by continued developments in the state of the art. Nevertheless, the report can be regarded as a good introductory text for those who wish to familiarize themselves with the main issues in this complex field.

This report is issued as part of the activities of the Buildings Energy Technology Transfer Program - a program administered by the federal department of Energy, Mines and Resources. The objective of this program is to develop competent energy conservation technologies for buildings of all types, and to deliver these technologies to prospective users.

The report falls in the category of Low-Rise Residential buildings - a category that is managed by Saskatchewan Research Council under contract to EMR.

The report does not necessarily reflect the views or policies of either Energy, Mines and Resources or Saskatchewan Research Council. However, the fact that it has been issued is an indication that each of these agencies is satisfied that it comes up to the standards of the BETT program and advances the state of the art.

D. Eyre
Saskatchewan Research Council

April, 1983.

SOMMAIRE

Une étude fondée sur des techniques modernes a porté sur l'incidence des mesures d'économies d'énergie sur les sous-sols de résidences de faible hauteur. L'étude comprenait une recherche documentaire et la consultation de spécialistes dans ce domaine. Dans le présent rapport sont exposés un résumé des résultats et une bibligraphie annotée des principaux documents consultés.

À la section 2, les auteurs examinent les principaux types de construction de sous-sols en accordant une attention particulière aux problèmes structuraux qui leur sont inhérents. Comme certaines techniques d'isolation peuvent accentuer ces problèmes, il se peut que les options de réfection en soient limitées.

Les conditions du sol de l'endroit peuvent souvent menacer sérieusement, à long terme, l'intégrité du sous-sol. Une fois l'isolant ajouté aux murs du sous-sol, la température du sol environnant est changée et il se peut que l'interaction entre le sous-sol et le sol en soit accentuée, ce qui limite les options de réfection et constitue un facteur déterminant aux fins de la décision de procéder ou non à la réfection. Les mécanismes d'interaction du sol peuvent découler de la nature même de celui-ci, comme dans le cas de l'expansion de l'argile, ou découler du mouvement des eaux dans le sol. La section 3 constitue un résumé de divers mécanismes d'interaction du sol et des eaux qui peuvent causer des dommages structuraux au sous-sol.

Aux sections 4 et 5 sont examinées les diverses techniques propres à l'application de matériaux isolants sur la face externe ou interne des murs du sous-sol, y compris une étude des avantages et inconvénients inhérents à chaque procédé. La section 6 expose les problèmes propres à l'installation d'un pare-vapeur en vue de réaliser une construction étanche.

La section 7 consiste en un aperçu général de la technologie de la réfection des sous-sols. Les auteurs y confirment la rentabilité élevée de la réfection du sous-sol, dont le coût peut être

récupéré au bout de 1,2 à 7,3 ans, selon le climat local, le type de combustible utilisé et le coût de ce combustible. Cette section se termine par une énumération des points qu'il serait bon étudier plus à fond.

La dernière section du rapport consiste en une bibliographie annotée des 55 sources de référence citées dans ce rapport.

Section 1

Introduction

1.1 Background

The present day basement evolved from a need to establish structural support for the dwelling on a stable base, free from the influence of frost action. Excavation between foundation walls provided a cool space for storage. This cellar space evolved into the modern basement.

Most basements today are partially finished, heated and used as an integral part of the living space of the home. Heat losses from uninsulated basement areas constitute a major conservation opportunity.

During the construction of new houses insulation can easily be applied to the exterior face of the basement walls. With proper construction practices and careful application exterior insulation is the best means of insulating a basement.

Exterior insulation is often not feasible for existing basements. They can be successfully insulated on the interior but careful attention must be paid to construction details. Interior insulation increases the risk of soil or water induced damage to the basement wall.

1.2 Objectives

The objective of this study is a state-of-the-art review of the effects of energy conservation measures on the basements of low rise residential buildings. It surveys the best methods of incorporating conservation measures in new basement design and basement retrofit. And it calculates the fuel savings obtainable from basement insulation.

1.3 Scope

Individual basement components are examined in Chapter 2. Figure 1.1 provides reference to specific basement components discussed in the chapter. The construction materials and insulation techniques most commonly used for the footings, floor, walls and other basement components are surveyed.

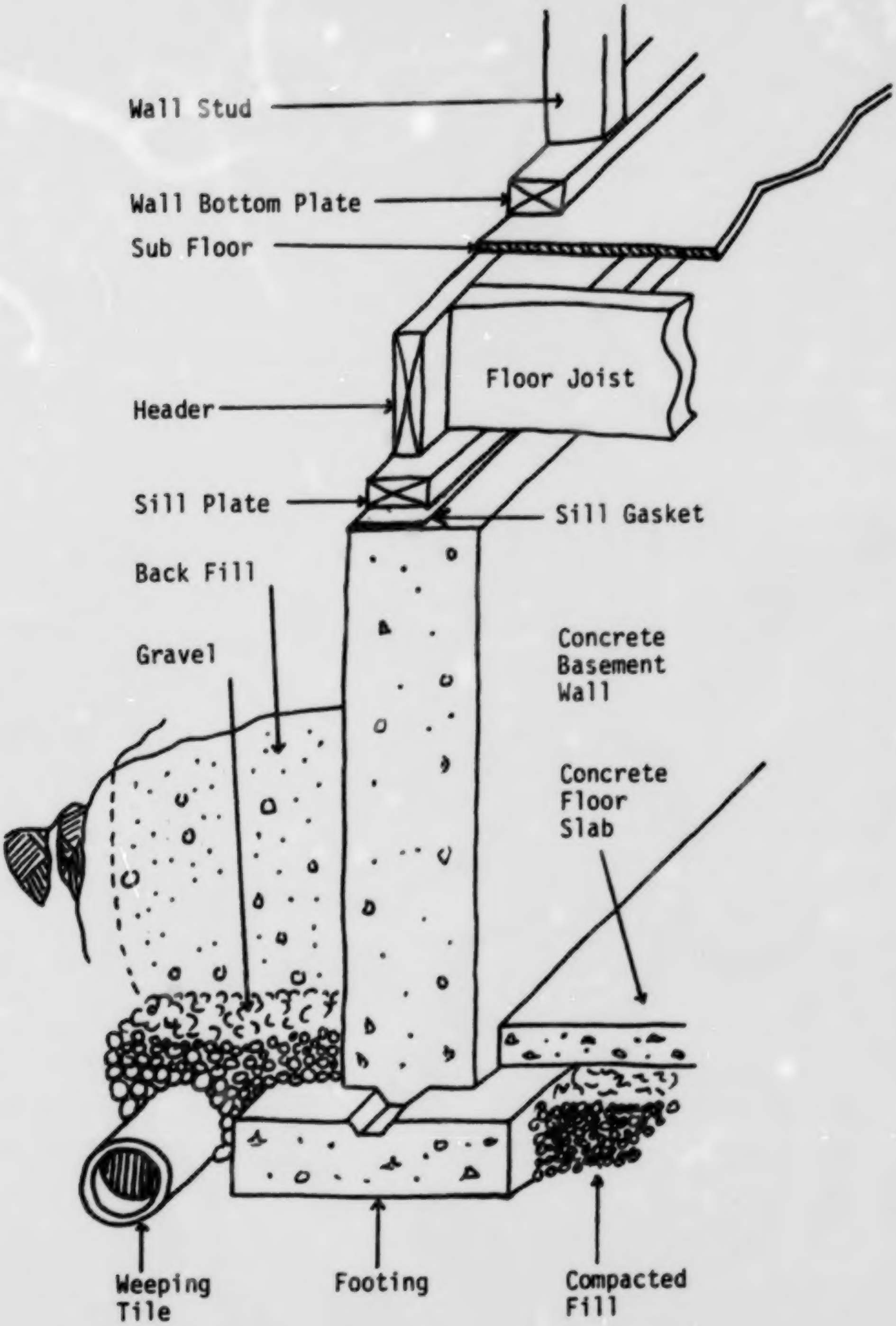
Basements can be seriously damaged by soil expansion and water freeze/thaw cycles. Application of insulation to the exterior, done properly, can reduce the danger of soil or moisture damage. Interior insulation, particularly if improperly applied, increases the risk of soil or moisture damage. Soil and water induced problems are discussed in Chapter 3.

Exterior insulation - materials, manufacturing methods, physical characteristics, installation techniques, problems and advantages - is discussed in Chapter 4. Interior insulation is treated in the same manner in the following chapter.

An air/vapour barrier is a critical element of effective insulation. Proper installation of an air/vapour barrier in an existing basement can be complicated, particularly in the header/joist area. Although air/vapour barrier installation is discussed throughout the study, there are enough unique aspects to justify a separate chapter; Chapter 6.

The last chapter summarizes the advantages and disadvantages of internal and external insulation. As well it develops an estimate of the potential energy savings available through insulation of basements. Areas requiring further study are also identified.

Figure 1.1 Basement Components


Wall Stud
Wall Bottom Plate
Sub Floor
Floor Joist
Header
Sill Plate
Sill Gasket
Back Fill
Gravel
Concrete Basement Wall
Concrete Floor Slab
Weeping Tile
Footing
Compacted Fill

Section 2

Basement Construction

The basement is situated in a dynamic mixture of rock, sand, soil, air and water that is warmed from below and tortuously frozen and thawed from above. Despite its variable environment, the basement must be built to stand firm, level and dry for as long as the structure above remains useful. Once erected, it is very difficult to alter.

This section looks at the two major components of a basement; the wall and the floor. These are discussed in terms of construction methods, type of materials and the application of insulation.

2.1 The Basement Wall

Several different materials have been used in basement wall construction in Canada:

- rubble (masonry and stone),
- clay brick,
- cast-in-place concrete,
- concrete block,
- pressure treated wood, and
- steel

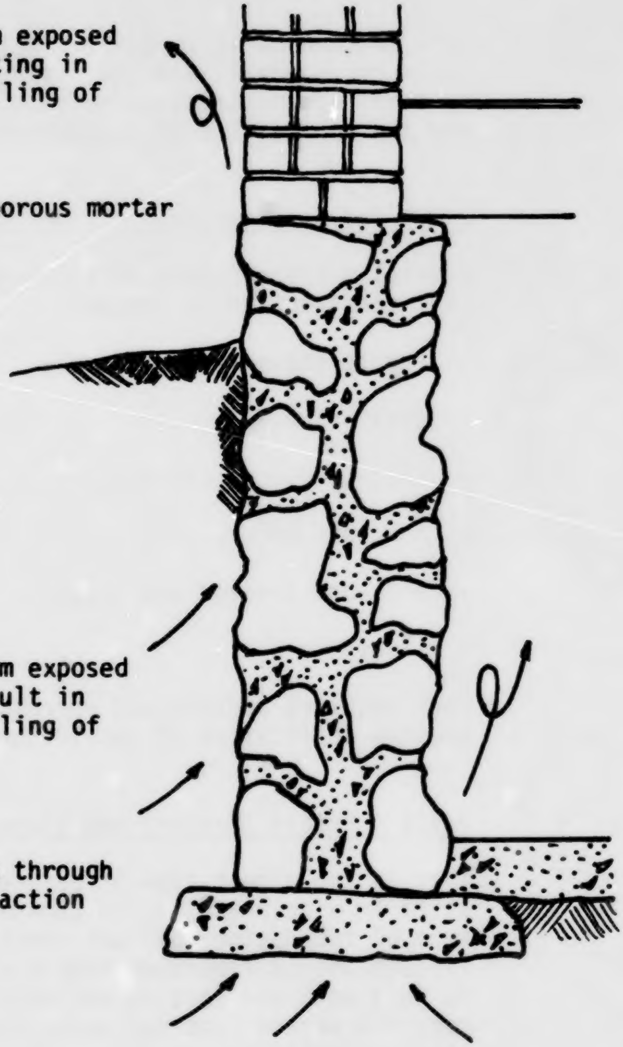
Each requires a different approach to both construction and the application of insulation.

2.1.1 Rubble (Masonry and Stone) Basement Wall

This is the oldest type of basement wall construction still in widespread use in Canada. Originally, this type of foundation wall was constructed with local field stone or limestone rubble stacked and mortared to form both the footing and wall. Later, the use of concrete spread footings under the rubble wall became standard building practice. These walls were massive and often irregular. They were usually constructed with the flat surface of each stone at the face of the wall. This leaves a high concentration of mortar at the core (Figure 2.1).

The mortar-rich portions of the wall are usually highly moisture permeable and can act as a wick, drawing ground water through the foundation and the base of the wall. The high moisture content of the mortar could

Figure 2.1 Rubble (Masonry and Stone) Basement Wall



Water evaporates from exposed face of bricks resulting in efflorescence or spalling of bricks and mortar

Water moves through porous mortar to bricks

Water evaporation from exposed basement wall may result in efflorescence or spalling of mortar

Ground water movement through mortar via capillary action result in some deterioration over time. However, water related damage is generally limited to exposed mortar joints where moisture evaporation to the basement occurs. These joints can be easily repointed with a lime-based mortar. The rubble material has a low permeability and so is unaffected by moisture. The high moisture levels found in basements with rubble walls is due in part to the absence of exterior waterproofing and weeping tile drainage systems.

In some cases, rainwater downpipes were drained to a sump under the basement floor and then to a well or sanitary sewer. These systems may leak or overflow and cause occasional flooding.

Dampness, leakage of water and occasional flooding are therefore problems commonly associated with rubble wall construction. If the basement is to be upgraded, excavation to the footing level and parging and damproofing of the exterior wall face is essential. Storm water must also be diverted from the base of the wall in some manner. While such an upgrading task may be unrelated to thermal upgrading, it provides a good opportunity for the installation of exterior insulation.

The application of interior insulation to a rubble wall lacking proper damproofing or exterior drainage is not advisable, particularly at the wall/joist intersection. The reduction of heat loss to the moisture saturated walls may cause freeze/thaw damage. If joist spaces are insulated, moisture drawn up through the wall will condense in the joist area and may cause eventual deterioration of the wood.

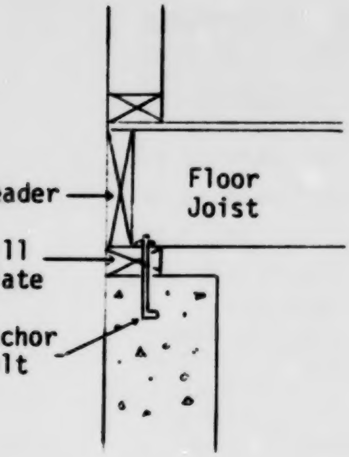
When applying insulation to the exterior of a rubble wall, it is essential that the wall be parged as smooth as possible. The insulation should be tight against the wall to eliminate pockets where water may collect or where air movement may cool the wall. The above-grade portion of the insulation should be covered with a protective coating and capped against water infiltration from the top.

2.1.2 Clay Brick Basement Walls

The use of clay brick as a basement wall material is of approximately the same vintage as rubble wall construction.

When insulating the basement area, caution should be exercised in insulating the joist space from the inside. If the joist space is insulated, moisture from the wall may condense in the cooler area behind the insulation and cause rotting of wood building components. Until more is known about this potential problem, it is advisable to leave interior joist spaces uninsulated.

Figure 2.2



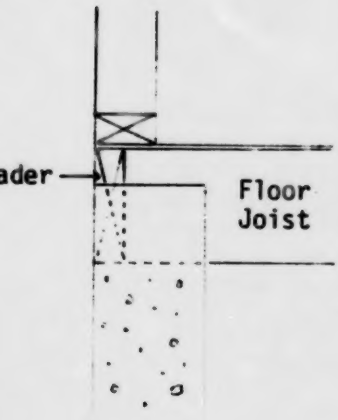
When applying insulation to the exterior of a clay brick basement, the wall should be parged. The insulation should sit flush with the wall to eliminate areas where water may collect or where air movement may cool the wall. The above-grade portion of the insulation should be covered with a protective coating and capped against water infiltration from the top.

2.1.3 Cast-in-Place Concrete Basement Wall

Cast-in-place concrete wall construction has been widely used in Canada since the early 1940's. Concrete is poured into a wood or metal form, vibrated and left to set for a minimum of two or ideally, seven days.

Figures 2.2, 2.3 and 2.4 illustrate three methods of connecting the floor joist and header assembly to the top of the basement wall.

Figure 2.3



The first method (Figure 2.2) involves setting threaded anchors in the concrete. These are used to secure a sill plate (as shown) as a base for the floor joist and header assembly. This method requires careful placement of the anchors and allows potential heat loss through air infiltration between the sill plate and the concrete.

Infiltration through this area can be significantly reduced by installing a sill gasket between the sill plate and the top of the basement wall. Vapour barrier installation around the header and sill plate is detailed in later sections.

Figure 2.3 illustrates a second method, in common use on the Prairies. Floor joists and header are positioned prior to pouring the concrete foundation wall. The forms are pre-notched to receive the joist assembly or extended between the joists to retain the concrete. Notched, re-usable forms quickly establish the joist spacing and are best used for subdivision housing.

The potential for heat loss through air leakage exists with this method as well. As both the wood members and the concrete dry, shrink spaces occur at the interface of these materials. It has been suggested that this type of construction, if insulated from the interior, may expose the embedded joists to moisture condensed from the wall and so lead to eventual rotting.

Figure 2.4

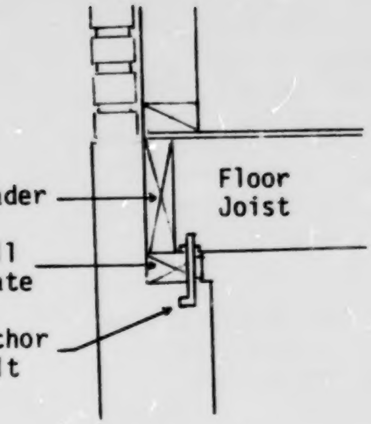


Figure 2.4 shows a method whereby the sill plate, floor joists and header bear on a pre-formed ledge at the inside face of the concrete wall. While sometimes used to support frame walls, this method is normally used in conjunction with exterior masonry construction. This approach is the best in terms of eliminating heat loss through air leakage.

Cracking is often a problem in unreinforced concrete walls. It can occur as a result of premature or improper backfilling or of shrinkage of high-water-content concrete while drying. Cracking can also occur if a wall is backfilled before it has had time to set. Heavy machinery or loads placed on the ground close to a recently constructed basement can also exert sufficient pressure to crack the wall. In the case of the pre-cast ledge method (Figure 2.4), cracking along the line of the sill plate would create a potential water transmission situation at grade.

Most ready-mix concrete is prepared in proportions of water to cement that provide maximum strength and durability. At the construction site, workers will often water down the concrete mixture as it is poured into the basement wall forms. The additional water dilutes the concrete and allows it to move more freely around the forms. Unfortunately, watered-down concrete loses much of its potential strength. The weakened concrete is also more susceptible to freeze/thaw damage.

In the construction industry, as opposed to the housing industry, a plasticizer is often added to the concrete to facilitate concrete flow without impairing its eventual strength. For some reason, plasticizers are not used by the housing industry.

Freeze/thaw damage usually manifests itself after a number of years of freeze/thaw cycles. Water within the wall and in small cracks, expands when frozen. When this is repeated over a number of cycles, serious damage to the concrete may result.

To date, there have been few documented problems of freeze/thaw damage in poured concrete residential basements. It may be that this isn't a serious problem because the amount of heat escaping from the basement ensures that wall temperatures never fall below freezing. Or it may be that freeze/thaw damage does occur but is not reported because the cracks only appear after a number of years.

The possibility of freeze/thaw damage occurring in basements insulated internally is a growing concern. Reducing heat escape from the basement may result in lower temperatures in the basement wall and subsequent freezing. Some authorities maintain that if a basement is well insulated from the interior, the wall will remain frozen throughout the winter and will not be subject to as many freeze/thaw cycles so the chance of damage may be reduced. However, a partially or poorly insulated wall may be exposed to a number of cycles over the course of a winter and therefore be subject to more freeze/thaw cycles and greater deterioration.

To date, there has been little research or investigation related to freeze/thaw action on fully or partially insulated walls. Deterioration due to freeze/thaw action can be expected to occur over a number of years and may be difficult to identify until major structural flaws appear. As a result, there is a need for further investigation and documentation of insulation related freeze/thaw damage.

Regardless of freezing action on the wall, cooling of a high-moisture content concrete as a result of interior insulation may cause further shrinkage of the wall and result in weakening of the structure and possible cracking.

Exterior insulation of a cast-in-place basement generally does not pose any insurmountable problems. The HUDAC Task Force on External Insulation of Basement Walls (in the first phase of its research) reached the conclusion that the application of insulation to the exterior face of the basement wall promised to overcome many of the shortcomings of the uninsulated and internally insulated walls, both in terms of energy consumption as well as overall performance (25).

While the installation of drainage tiles, pipes or gravel drainage beds are required in urban residential construction along with parging and dampproofing (2), it is not always done correctly. These and other standard practices (e.g. pouring concrete) need to be re-affirmed in the residential construction industry.

2.1.4 Concrete Block Basement

The use of concrete block in the construction of basement walls started around 1930. They are still widely used today, particularly in small building projects or in isolated areas where ready-mixed concrete is not economic or readily available. Blocks normally used for residential construction have a face dimension 20 cm x 40 cm and are available in thicknesses ranging from 15 cm to 30 cm. A block wall is normally placed on a poured concrete footing.

Perhaps the most serious shortcoming of the concrete block wall is the continuous cavity created by the hollow block construction. Air convection currents travelling the height of the wall can decrease the insulative and airtightness effect provided by the soil. Filling of block cavities, or external insulation of the wall, can overcome this problem.

2.1.5 Preserved Wood Basement Wall

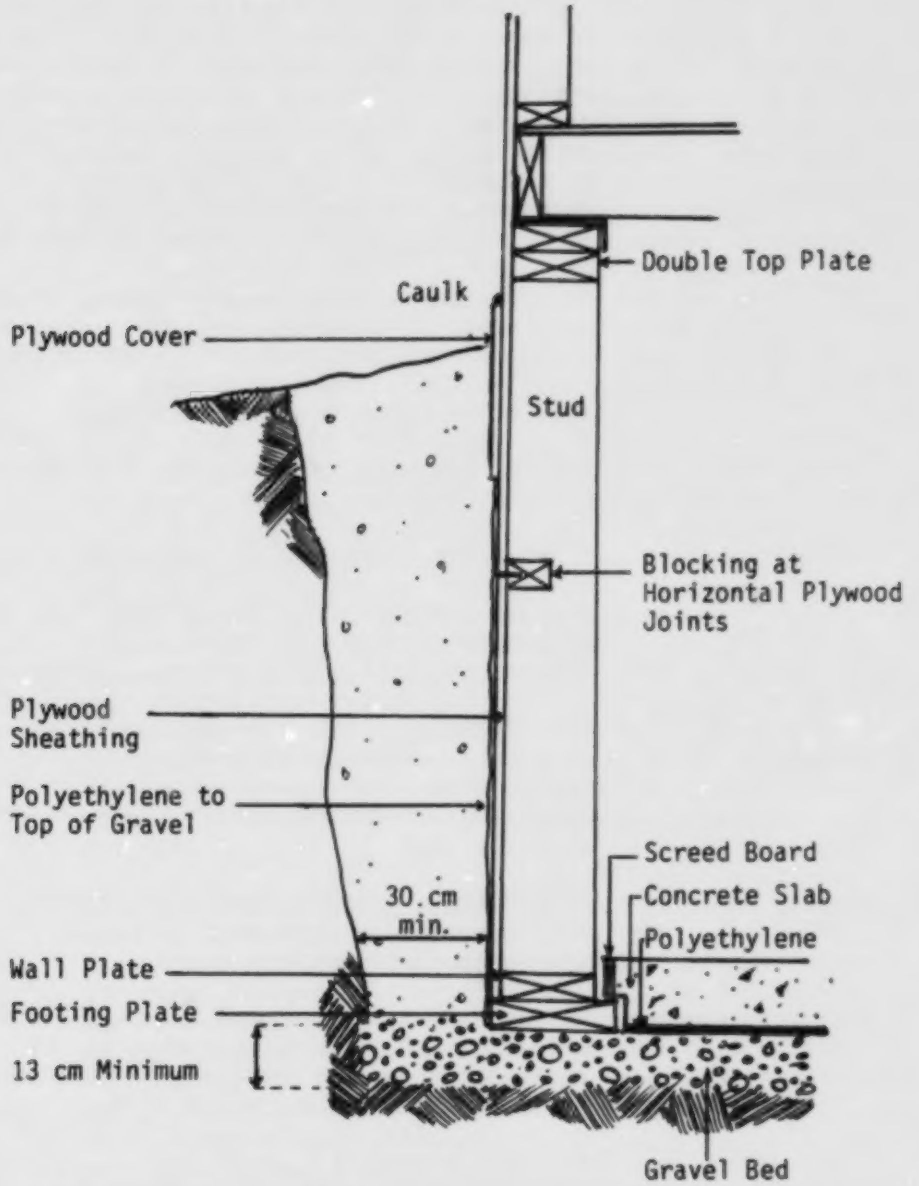
Preserved wood footing and wall systems have been used in Canada for about 10 years. Their popularity is growing and will likely continue, given the increasing cost of buying and transporting traditional foundation materials. A distinct advantage is the relative speed with which walls can be erected since no drying or curing time is necessary. The wall can be easily insulated between the vertical members or at the exterior face.

An additional advantage associated with preserved wood basement walls is that they have a "finished" appearance upon completion.

All wood used in this type of construction is treated with chemical preservatives that resist attack by decay organisms and termites. A good perimeter drainage system ensures the longevity of the structure.

Figure 2.5 shows a typical cross-section through a wood foundation wall. The wood foundation plate sits directly on a bed of compacted gravel about 13 cm thick. This gravel bed acts as part of the perimeter footing and helps distribute construction load to the undisturbed soil below (8).

Figure 2.5


Double Top Plate
Caulk
Plywood Cover
Stud
Blocking at Horizontal Plywood Joints
Plywood Sheathing
Polyethylene to Top of Gravel
Screed Board
Concrete Slab
30.cm min.
Polyethylene
Wall Plate
Footing Plate
13 cm Minimum
Gravel Bed

To minimize soil contact with the exterior plywood sheathing, 6 mil polyethylene sheeting is applied to the plywood face from the base of the wall to top of gravel. As a moisture barrier, the polyethylene covers the plywood joints and helps direct ground water to the gravel base.

Wood basement construction is not without its limitations. Levelling of footings on the gravel pad can be tedious and time consuming. Only galvanized or stainless steel nails and staples can be used.

A critical aspect is that loading on walls should not exceed a lateral pressure of 480 kg/m^3. This is a relatively low tolerance considering that standing ground water can exert a pressure of almost 1,000 kg/m^3. Good drainage must be insured and maintained at all times. Problem soils, such as shifting clays, create a particular concern in terms of lateral loading.

All preserved wood foundations should be constructed according to the guidelines set out in the Construction Guide for Preserved Wood Foundations published by the Canadian Wood Council (8). The Canadian Standards Association (CSA) is presently preparing a standard covering design and construction of preserved wood foundations (S406-M).

The compacted gravel bed also provides a positive drainage base extending a minimum of 30 cm beyond the outer wall footings. A similar material with good drainage characteristics is used as backfill around the walls. The porosity of the backfill material is decreased towards the finished grade level. The top 30 cm layer of backfill should be the least porous material with the finished grade sloping away from the building wall (18). Material excavated for the foundation should only be used as backfill if the soil is naturally free draining and the water table deep.

By extending beyond the exterior face of the wall and up to grade, the gravel fill provides positive drainage for surface water to a basement sump pit. This system does not use perimeter drain tiles as the gravel fill eliminates the need for such a system.

Basement floor systems include a poured concrete slab on the gravel bed, construction of a wood sleeper floor on the gravel bed or construction of a suspended floor with a crawlspace between the gravel and basement floor. In each case, the gravel bed is covered with a sheet of polyethylene serving primarily as a moisture barrier. If desired, the floor can be insulated.

Preserved wood basements are customarily insulated with batt type insulation in the wall cavity. Additional insulation can be applied to the exterior. Some new external insulation materials, such as drainage membranes and compacted fibreglass insulation, have the added advantage that they can also serve as a substitute for a draining gravel backfill. These types of capillary breaking surfaces will be discussed later in greater detail.

2.1.6 Steel Basement Wall

Steel foundation walls have been used experimentally in Saskatchewan and other parts of Canada for the past ten years. They will shortly be marketed on a commercial basis.

Those installed in Saskatchewan have remained dry and structurally sound, resisting lateral pressures exerted by local prairie clay soils (20). An advantage of using a metal basement is the flexible nature of the metal. This enables the basement to withstand varying soil pressures without incurring structural damage.

Initial experimentation with basements of steel construction found that the steel could be subject to rapid deterioration by dielectric and galvanic action due to grounding. The combination of a mild, naturally occurring electrical charge in the ground with the moist soil in direct contact with the steel basement wall was found to induce corrosion. One remedy tested involved electrically charging the basement walls to negate the effect of the in-ground electrical charge. Alternatively, insulating the exterior of the basement wall will keep water away from direct contact with the wall, thereby eliminating the effect of ground currents.*

A steel basement wall can be constructed on either a metal or concrete footing. In both cases, the wall is fastened to the exterior of a channel or an L-shaped metal bracket using bolts or screws. The channel is fastened to the concrete footing using special screws set in pre-drilled holes. The channel can also be set directly onto a gravel bed. In each case a bituminous coating is applied to the footing or gravel bed, and the metal bracket to ensure water-tightness (13). Figure 2.6 details the different components of a steel basement design as developed by Dofasco of Hamilton, Ontario.

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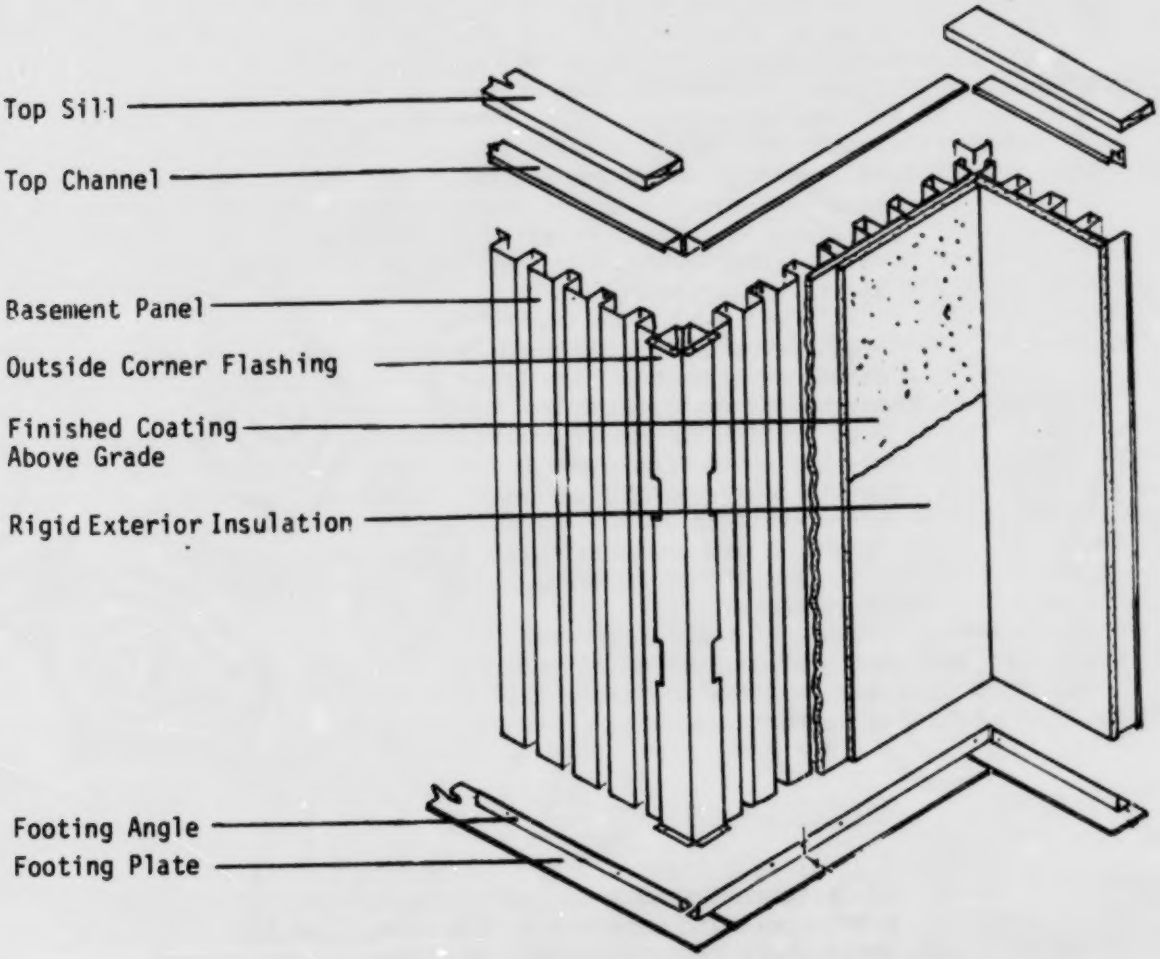
*Discussions with A. Zakrzewski, Dofasco Inc., Hamilton, Ontario.

Figure 2.6 Assembly of Dofasco Steel Basement Components


Top Sill
Top Channel
Basement Panel
Outside Corner Flashing
Finished Coating Above Grade
Rigid Exterior Insulation
Footing Angle
Footing Plate

Source: Dofasco Steel Basement System Manual, February 8, 1982 Issue, Dofasco Inc., Hamilton, Ontario. Printed with permission.

Insulation in the form of rigid boards can easily be affixed to the basement wall with mechanical fasteners. Tests conducted by HUDAC on the application of various exterior insulations to a steel basement found that adhesive coatings and fasteners did not satisfactorily hold the insulation in place (25).

2.1.7 Other Materials in Current Use for Basement Walls

Foam Form Blocks

Foam form blocks are a hollow core insulating block made of polystyrene foam. The units are stacked in place on a poured concrete footing just as in conventional basement wall construction. The hollow cores of the units are steel reinforced and then filled with concrete. The unit then provides the structural as well as insulating properties of the wall. The heat generated by the setting of the concrete is sufficiently retained to prevent freezing at temperatures as low as -9°C. This reduces the need for weather protection during winter construction.

Problems have occurred in using the blocks. The wall cannot be poured to more than four feet in height or the weight of the concrete causes the blocks to break. Wood framing is therefore required to support the blocks, which negates one of the principal selling points of the manufacturers. Experience shows that using the foam form blocks is much slower than using form work and the construction problems encountered make this system more expensive than a conventional system.

The economics of using this product are in some doubt as experience now shows that the installation process is labour intensive.

Sparfil Block System

Sparfil is a lightweight, fire-resistant insulating concrete comprised principally of expanded polystyrene beads, portland cement and fine sand. The expanded polystyrene beads represent approximately 60 percent by volume of the finished Sparfil blocks. Sparfil blocks range in size from 10 cm to 30 cm with RSI values between 0.7 and 2.1. The 20 cm, 25 cm and 30 cm blocks are also available with the voids pre-filled with polyurethane foam to achieve RSI values of 3.3, 4.0 and 5.8 respectively.

The "Sparfil block system" consists of laying the first course of block in a bed of mortar on the poured concrete footing and dry stacking the remaining courses. The blocks are easily cut with a hand saw and can be easily nailed. The wall is moistened and a 125 mm coating of surface bonding cement is applied to both sides. The surface bonding cement is a portland cement, sand, glass fibre product that may be trowelled to a smooth or textured surface. The glass fibre acts as a reinforcing agent throughout the surface bonding cement, thus creating a uniformly strengthened material.

Surface Bonding Cement

Surface bonding cement is used as a replacement for mortar in both structural and non-structural assembly of concrete block walls. It can also be used as a decorative coating, as a protective coating over foam board insulation and as a parging coat for basement walls.

The surface of the concrete block must be clean from soils, paint, efflorescence, oil, or any material that will interfere with proper bonding. The first course of block must be placed in a bed of mortar and leveled, the remaining courses are dry-stacked. Plastic shims or galvanized brick ties are used when necessary to level the courses while drystacking. Before applying the bonding cement the wall must be dampened, and kept damp during application. This ensures a good bond and aids in spreading the material. The bonding cement is spread into the joints and completely over the block at a minimum surface thickness of 3 mm on both sides of the block. When it is necessary to apply the material in lifts, the first stage is stopped at the middle of the course of block so that the next stage will lap the block joints. Finishing of the surface may be done in a variety of stucco-like textures using sponges, trowels, wooden floats and brushes.

2.2 The Basement Floor

Poured-in-place concrete continues to be the most frequently used material for residential basement floor construction in Canada. It is also used for slab-on-grade construction and as a base for heated crawl spaces.

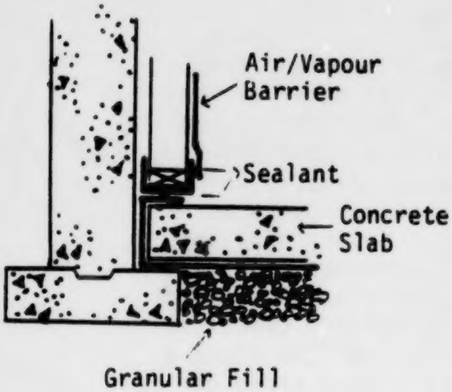
Wood frame floor systems have been used in combination with preserved wood basement wall construction. House builders, however, prefer concrete slabs in order to reduce material and labour costs. Where a finished floor is required in a full basement, there are a number of approaches which can be used.

The following considers the various forms of basement floor construction now in use, the materials used and the application of insulation.

2.2.1 Poured-in-Place Concrete Slab

Conventional construction practice calls for a 10 cm concrete slab on 13 cm compacted gravel. Most builders place 6 mil polyethylene between the slab and the gravel base. This prevents moisture movement from the ground into the basement space and also reduces the infiltration of radon gas which is generated mainly in the soil around the house.

Figure 2.7



If the moisture barrier is fairly intact, it can also serve as a vapour barrier. From a practical point of view it is very difficult to keep the polyethylene sheet from being punctured as the concrete is being moved around with wheelbarrows and shovels.

As illustrated in Figure 2.7, the moisture barrier can also be wrapped around the edge of the slab and joined to the wall component vapour barrier to ensure the integrity of the airtight house envelope. Unless a considerable amount of care is taken with this procedure, the polyethylene sheet will be shredded where it projects above the edge of the slab, and there will be little chance of achieving an airtight joint.

In theory, the moisture barrier can be placed either on top or beneath the compacted gravel base. Some consideration should be given to the latter practice since less damage can occur through installing the gravel base. It also places the barrier that much closer to the source of moisture.

The question of whether to insulate a basement floor slab has not been resolved. Traditionally, heat losses through uninsulated floor slabs in houses has played a relatively small role compared to the overall space heat losses. With the advent of super air-tight and insulated houses, the fraction of heat losses through uninsulated basement floors is very much larger. While the total amount of heat loss through the slab or floor system may not have changed significantly, up to 50 percent of the auxiliary space heating requirements may be lost through the basement floor.

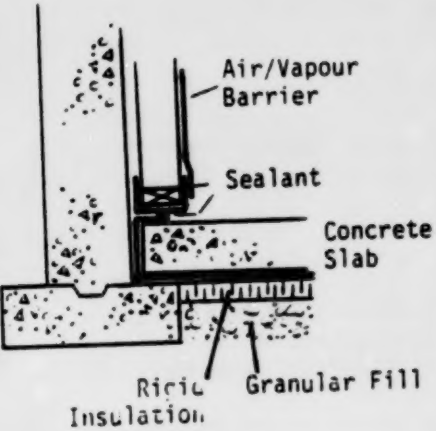
A preliminary report on the uninsulated basement floor heat loss in 14 low energy houses in Saskatoon (4) examined the net heat transfer rates to the basement floors by radiation and convection. A new method of analysis was used to determine these heat losses and initial results suggest that basement floor heat losses in low energy houses may be two or three times greater than traditional methods of calculation would suggest.

While this study includes a method of under-slab insulation, it should not be concluded that it is advocated since a number of problems can arise.

Where the interior face of basement walls are insulated over their full height, most of the heat supplied to the wall footings comes through the basement floor. If the footings sit on expansive soils and the temperature of the soil is allowed to go below the freezing point, heaving and cracking of the house foundation could result.

Figure 2.8 illustrates the application of rigid polystyrene (25 mm, RSI 0.9 to 50 mm, RSI 1.8) under-slab insulation. As with the moisture barrier, the rigid insulation can be damaged during the concrete pouring. Precautionary measures in this area implies additional labour and, hence, cost.

Figure 2.8

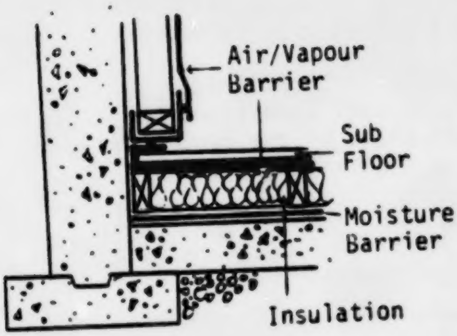


2.2.2. Wood Frame Floor on Concrete Slab

Homeowners who install a finished subfloor on an uninsulated concrete slab have an opportunity to include moisture and vapour barriers as well as insulation at a relatively low cost. Figure 2.9 illustrates the details for this procedure.

This practice is good from an energy-efficiency point of view, but should not be used where the foundations sit on unstable soil. The subfloor conceals evidence of progressive deterioration of the concrete slab.

Figure 2.9



2.2.3 Basement Floor Construction with Preserved Wood Foundations

Figure 2.10

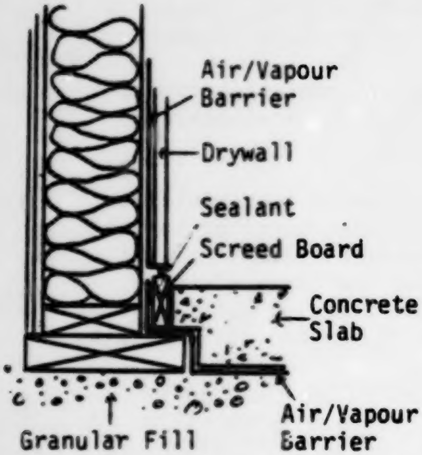


Figure 2.10 shows the construction details at the point where the concrete floor slab meets the base of a preserved wood foundation wall. Some moisture infiltration can occur around the foot of the foundation, between the wall and the slab. This is reduced by joining the wall vapour barrier to the floor moisture barrier on the line of the screed board, as shown.

The construction sequence is as follows:

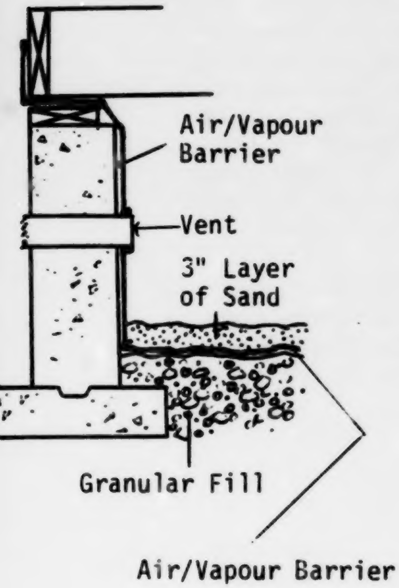
- Preserved wood foundation wall with footing plate is constructed on compacted granular fill
- Moisture barrier (and rigid insulation if applicable) is laid on fill in basement floor area
- Moisture barrier is carried up the inside face of the wall framing and temporarily stapled above the finished floor line to the vertical framing members
- A continuous wood screed board, sized to project above the finished surface of the concrete slab, is nailed to the base of the vertical framing members. Before fixing the screed board, a continuous line of sealant is applied to the vertical face of the moisture barrier.
- The concrete floor slab is poured in place using the screed board and foundation plate as edge formwork
- The perimeter excavation can now be backfilled, using granular material in clay soil conditions. The screed board, anchored in place by the concrete, will prevent the wall framing from shifting under backfill loading.

2.2.4 Floor Treatment in Heated/Unheated Crawl Spaces

The approach to insulating a heated crawl space is detailed in a following section of this study.

Where a crawl space is unheated and not used as a storage area, the floor can be either undisturbed soil or compacted granular fill. In each case, a 6 mil polyethylene moisture barrier should be spread over the base material and carried up the sides of the foundation wall to the outside of the floor header at grade. The moisture

Figure 2.11



barrier restricts the build-up of ground generated moisture in the crawl space and can be protected from damage during construction by a layer of sand. Figure 2.11 illustrates this procedure.

A heated crawl space is usually used as a storage area and therefore requires a solid floor system which can be insulated. The principles of full basement construction with respect to the location and installation of moisture barriers and insulation can generally be applied here. The main factors are to provide insulation in the right place, and to protect against the effects of moisture build-up.

2.3 Moisture Control

Barriers to moisture and water transfer through basement wall systems serve two functions: dampproofing and waterproofing. Moisture barriers are applied to either the exterior or the interior face of the wall.

The following describes the dampproofing and waterproofing process and methods of application or installation.

2.3.1 Dampproofing

Dampproofing materials act to interrupt the capillary draw of moisture into the wall system. The three most commonly used materials for dampproofing are cement-plaster, asphalt coating and polyethylene sheeting. The use of polyethylene as an air/vapour barrier is discussed later.

Dampproofing materials cannot be expected to block water transfer in that they are either too thin, have too little resistance to bridging cracks or deteriorate too quickly. However, use of multiple layers of some dampproofing materials produces a wall that is considered waterproof.

Cement-Plaster Coating (Parging) - Parging is the application of one or two coats of cement-plaster. This is applied in 60 mm layers; the first firmly trowelled over the wall surface and scored to provide a good bond with the second coat. For maximum water resistance, the second coat should be moist-cured for at least 48 hours. The parging technique can be used either to level uneven walls to receive rigid board insulation or as a base for the application of a bituminous coating.

Asphalt Coatings - Asphalt coatings can be applied hot or cold, and can be sprayed, brushed, or trowelled on. In general, trowelling gives a better job than spraying since a denser layer with better adhesion is obtained. Hot asphalt emulsions become brittle when they cool and hence lose their effectiveness. Cold asphalt applications will bridge minor cracks but will not seal structural or settlement faults. Asphalt emissions are slowly soluble in water, thus the water resistant characteristics of the wall will be reduced over time.

Polyethylene Sheet - Polyethylene film overlapped at the joints but not sealed is considered by some to be a good dampproofing material. It is capable of bridging minor wall cracks but must be installed carefully to avoid tearing and puncture.

2.3.2 Water-proofing

Water-proofing materials are designed to stop water penetration into or through a wall system. Not all techniques or materials are developed to withstand continuous hydrostatic pressure, however.

Water-proofing materials include built-up membranes and polyethylene film embedded in mastic.

Built-up Membranes - Membranes consist of layers of asphalt pitch, alternated with felt or fibreglass reinforcing. Three or four ply are necessary to obtain satisfactory waterproof characteristics. Fibreglass should be used rather than organic felts since these will rot if repeatedly saturated.

There are three disadvantages to the membrane application:

- If it should leak in one place, the adhesion is usually not good enough to prevent water from travelling behind the membrane and appearing inside at a point remote from the actual leak.
- On a vertical surface it is difficult to apply pitch hot enough to saturate the fibreglass.
- The membrane does not have any resealing capability at underground temperatures.

Polyethylene Embedded in Mastic - Mastic is applied to the surface of the wall and the polyethylene sheets are embedded in it, with generous overlapping at the joints, which are also sealed with mastic. If rigid foam insulation is to be applied over the water-proofing layer, care must be taken to ensure that the mastic adhesive has cured. If the coating has not properly cured, the rigid foam insulation in contact with the water-proofing may be subject to deterioration.

2.3.3 When Water-proofing/Dampproofing is Required

According to Residential Standards 1980, all basement walls and floors must at least be dampproofed(2). Dampproofing,however, is not necessary for a slab floor if the slab is supported on a base of granular fill. Water-proofing is required for basements constructed in areas where hydrostatic pressure (e.g., high ground water table) occurs. All water-proofing and dampproofing materials must conform to standards set out by the Canadian General Standards Board (CGSB). Water-proofing and dampproofing is only applied to ground level on basement walls (12).

2.4 Drainage and Backfilling

Ground water around the basement/foundation system is controlled by keeping the water table below or at the basement floor level. This can be accomplished through the installation of drainage tiles, pipes or a granular drainage layer.

2.4.1 Drainage Tile and Pipe

Drainage tile and drainage pipe are placed around the outside perimeter of the foundation at the footing level. The tile or pipe should be laid on undisturbed or well compacted soil and covered with at least 15 cm of crushed stone or other coarse clean granular material (2).

Until recently, clay tiles were used for most residential construction. To install a tile system, tiles are placed with butt ends spaced 1 cm apart and then covered with a water permeable felt (or sacking) to prevent silting. Granular fill is then placed over the tiles (2). Perforated plastic pipe is now often used in place of clay tiles because it is better able to withstand soil pressures and disruption by tree roots. The plastic pipe is installed in long continuous lengths and therefore does not require the special treatment required for a clay tile system.

2.4.2 Granular Drainage Layer

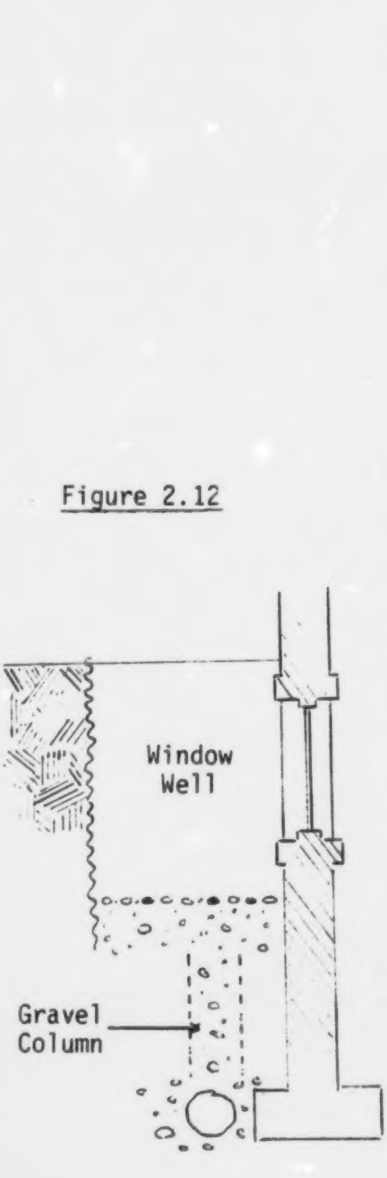
The use of a granular drainage layer in place of a perimeter tile or pipe drainage system was briefly discussed in the section dealing with wood basements (2.1.5). The granular drainage layer is created by installing a continuous layer of coarse crushed stone to a depth of at least 125 mm below the intended building foundation. The gravel layer should also extend a minimum of 300 mm beyond the outside edge of the footings. The entire layer should be graded to allow drainage to a sump. Water collected in the sump is discharged into a sewer, drainage ditch or dry well (2,8).

2.4.3 Backfilling

Backfilling should occur in several layers around the perimeter of the basement. This minimizes the stresses on the foundation wall and the risk of damage to waterproof coatings, exterior insulation and the drainage system.

Backfilling of originally excavated material should only take place if that material has good drainage characteristics. Use of clay or silt based soils as backfill may lead to future problems. In some cases, a layer of low permeability clay or silt is used for the top layer of backfill. In accordance with Section 14F of Residential Standards 1980, the area around the building should be graded so that water will not accumulate at or near the building (1). Such a non-permeable layer facilitates runoff away from the building and minimizes the water runoff load placed on the drainage system.

Figure 2.12



Basement windows that extend below grade require special attention. A window well, usually constructed of galvanized corrugated sheet metal, should be installed around the window. Surface runoff should be directed away from the walls and window wells. If the backfill material beneath the window is suspected of having poor drainage characteristics, the bottom of the well should be connected to the foundation drainage system via a 15 cm diameter column of crushed stone. Gravel should fill the window well to just below window level, as in figure 2.12.

Section 3

Soil and Water Induced Problems

Changes in soil and water conditions can affect a basement. Expansion and contraction of the surrounding soil with changes in temperature or moisture content can damage a basement wall. Water causes two types of problems: cracking as a result of freeze/thaw action and gradual deterioration of basement wall materials. The water may be surface moisture, soil moisture or condensation but the potential problems are the same in all cases.

While soil around the basement is often thought of as an insulator, many factors including soil type, ground moisture, basement composition and height above the ground combine to determine the actual thermal behaviour of the structure. In addition, surrounding vegetation, ground surface material and slope as well as the existence of in-ground drainage systems can all affect thermal performance. These same factors also have a significant effect on the longevity and structural integrity of the foundation.

The thermal conductivity of a water saturated soil can be 10 times greater than that of a similar dry soil (35). It is therefore very important to ensure that soil adjacent to the basement wall is well drained and that surface runoff is diverted from the base of the house. Cold water flowing through the soil, even at a relatively slow rate, can carry a tremendous amount of heat from both the basement and surrounding soil.

3.1 Soil Induced Damage

3.1.1 Expansive Clay Soils

Expansive clay soils, of the type commonly found on the Canadian prairies, will shrink when dried or swell when wet, to the extent that serious damage can be inflicted to foundation walls, footings and floors. Damage can range from minor cracking to differential movement of footings and walls. Shifting clays can exert both vertical and lateral pressures on a wall.

Generally the change in volume of clay soils is directly proportional to the change in moisture content of the soil. As a result, areas which experience distinct dry and rainy seasons are subject to greater expansion/contraction cycles. However, the clay is also sensitive to relatively small moisture differences due to the local microclimate. For example, the growth of a large tree may significantly dry the soil close to a building. If the tree is removed, the resulting increase in soil moisture would cause the clay to swell and perhaps damage the building foundation. The combined effect of a cool, shaded, north-facing wall and a sun-baked, southern exposure could result in soil shrinkage occurring to the south and expansion to the north with differential movement of a building's foundation.

Given the sensitivity of expansive clay soils, any alteration of the moisture equilibrium will affect ground stability. Changes of soil volume can be expected to occur when:

- surface or subsurface drainage patterns are altered;
- trees or shrubs are added or removed;
- soil temperatures are changed;
- the excavated site is left exposed over a long period; and
- lawn watering adds additional moisture to the soil.

Potential damage to foundations can be minized through:

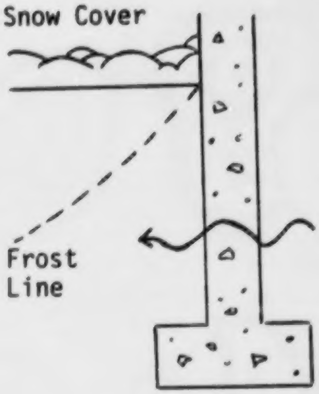
- use of special construction techniques such as suspended basement floors and pile and beam foundations that can accommodate moderate soil movement; and
- measures taken to reduce variations in moisture content of the soil around the building, such as backfilling with non-expansive material and ensuring good drainage around footings and under basement floors.

Remedial control of soil movement is often achieved through careful lawn watering. The degree of seasonal volume change can be reduced and localized shrinking as might occur around trees or shrubs can be compensated for by appropriate watering practices.

3.1.2 Soil Freezing and Frost Heave

Penetration of frost can also cause soil expansion and certain types of freezing action can induce soil movement. The heat lost from a heated uninsulated basement usually keeps the soil adjacent to the basement structure from freezing. The effects of freezing on a basement can include cracking, movement of walls and shifting of all, or parts of the structure.

Figure 3.1



A fundamental rule of basement construction is that footings should be located on stable ground below the level of frost penetration (2). A second rule is that water should be prevented from accumulating around footings and walls (2). This is achieved through the installation of suitable backfill and a good foundation drainage system. If these two rules are followed, it is highly unlikely that frost or freezing related damage can occur.

Frost penetration of the soil is moderated by the amount of moisture in the soil, its drainage characteristics and the ground cover. Grass, leaves and snow can provide some degree of thermal resistance to frost penetration.

Figure 3.1 shows a cross-section of an uninsulated, heated basement and where the frost line might occur if there is a normal level of snow cover. If insulation is added to the wall and the heat loss to the soil reduced, the frost line could move closer to the wall as in Figure 3.2.

Figure 3.2

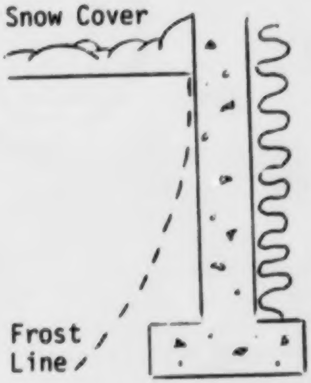


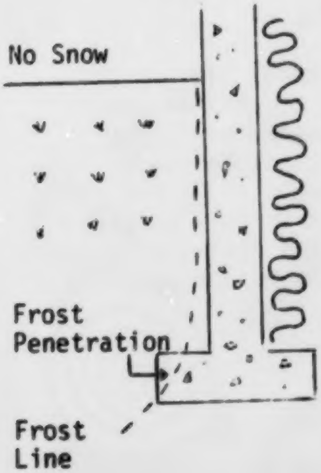
Figure 3.3 shows frost penetration to the footings of an insulated or unheated basement. This could only happen if:

- the basement floor is unheated or insulated
- the soil is very wet from late fall rains and is poorly drained
- freezing is quick and sustained due to low temperatures over the winter
- there is little or no snow cover.

If the frost line were to move to the basement wall, adfreezing could result in the cracking, shifting or heaving of the wall. Foundation damage would occur as a result of two separate but simultaneous effects:

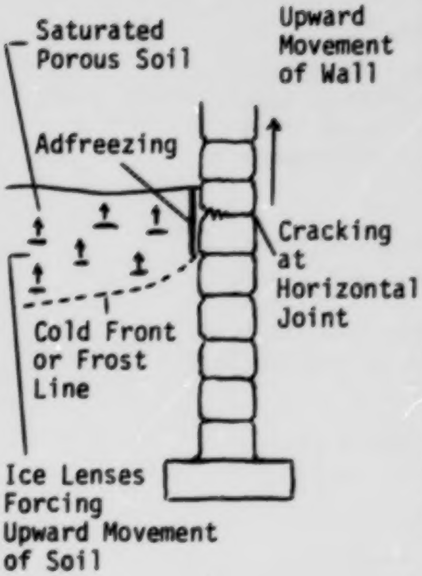
- soil freezing directly to the basement wall; and
- uplift pressure occurring as a result of freezing action in the soil.

Figure 3.3



The combination of soil freezing to the basement wall and uplift action can exert enough pressure on the wall to raise it off its footing. Lateral cracking of the wall at its midpoint is also a possibility, given that concrete and concrete block construction have no strength in tension.

Figure 3.4



Uplift pressure in freezing soils is usually a result of ice lensing. Ice lensing most commonly occurs in soils that possess high capillary characteristics (ability to hold moisture) such as fine sand or silt. A high water content in the soil (e.g., as a result of a high water table) is a necessary precondition for lensing to occur. When the ground freezes, a cold front is formed along the bottom of the frozen soil. When ground water seeping up from below comes in contact with the cold front, it freezes and expands, exerting uplift pressure on the soil. As long as the cold front or freeze line exists, the formation of ice pockets or ice lenses will continue,along with upward heave. Ice lensing will only cause movement of soil in a vertical plane and will not exert lateral pressures on a basement wall. Figure 3.4 graphically illustrates an ice lensing action.

Serious damage to a foundation can occur if frost penetrates to the footing level. This could result in adfreezing occurring over the entire length of the wall. Ground heave under the footing is also possible. Not only can uplift pressure to the footing cause serious structural damage, but freezing and the subsequent thawing of the earth below the footing will reduce ground stability.

3.1.3 Exterior Insulation

While exterior insulation is subject to adfreezing and heave damage, there appears to be no indication of structural damage to walls or movement of footings (22). Damage to the insulation may result in subsequent heave losses, precluding further freezing action. In soils where adfreezing damage may be expected, a single or double sheet of polyethylene is placed between the rigid foam insulation and the soil. The polyethylene acts as a "slip coat", preventing soil from coming in direct contact with the exterior insulation.

A slip coat should not be used with mineral fibre exterior insulation where its drainage properties are desired. Trials and tests of this type of insulation in Canada and ten years' working experience in Sweden have not shown adfreezing to be a problem (49). The good drainage characteristics of this material, combined with an effective backfill and foundation drainage system, reduce the chances of adfreezing occurring.

Rigid foam insulation is often placed below grade in a nearly horizontal position sloping away from the wall. While this is often looked upon as a slightly less efficient alternative to full foundation insulation, it does inhibit the penetration of the frost line to the footings. Compared to full wall insulation, horizontal insulation may also better utilize below grade mass for summer cooling.

3.1.4 Interior Insulation

If the perimeter of a new house is well drained, adfreezing damage of the basement wall with interior insulation is unlikely to occur. A coat of bitumen moisture proofing material, as required in all new construction (2), provides only temporary protection to a basement wall which is subject to adfreezing action. The bitumen coating acts as a slip coat and will shear from the wall under adfreezing and uplift action (48). Subsequently, this may lead to groundwater leakage at the wall face.

Where soil conditions lead to adfreezing, a polyethylene slip coat should be installed over the waterproofing material. Further, it is essential that the bitumen coating has fully cured before applying the slip coat.

In a retrofit situation where insulation is being applied to the interior of an existing basement wall, the chance of heave damage is considerably greater, particularly if no foundation drainage or exterior water-proofing exists. A high relative soil moisture content, combined with the lack of a slip coat, such as might be provided by water-proofing material, could make the basement wall vulnerable to freeze and heave damage. The probability of damage increases if the insulated wall is close to a driveway or parking spot regularly cleared of snow.

Often garages and other ancillary structures are subject to heave damage. Even when the structure is attached to the house, builders seldom insulate or water-proof below grade. A direct bond between the soil and the below grade portion of the structure can occur under certain conditions. Porches and concrete steps may also be subject to similar problems.

Both new and existing homes could be subject to frost heave below foundation footings if insulated from the inside. Complete insulation of the basement wall and floor could cut off all thermal input to the soil from the basement area permitting deep frost penetration. As a precautionary measure and where feasible (e.g. where excavation is necessary) external capping of the foundation footing with a layer of sloped rigid insulation can provide extra protection. Care should be taken to ensure that good drainage is maintained and water build-up is not allowed to occur near the basement wall.

3.2 Water Induced Damage

3.2.1 Freeze/Thaw Damage

Freeze/thaw damage can occur when building components containing moisture go through a number of freeze/thaw cycles. The freezing of the moisture plus the general thermal stresses exerted over the height of the wall in combination lead to eventual weakening of the wall (30,31).

Freeze/thaw damage is generally associated with older rubble and clay brick construction where basement walls are subject to high moisture levels. Many of these homes are also without direct basement heating. Depending on outside conditions, walls may be at an equilibrium point during the winter that forces them to go through a number of freeze/thaw cycles. It has been suggested that perhaps only poorly insulated houses will be subject to a potentially harmful number of freeze/thaw cycles. Well insulated walls will stay frozen throughout the winter and uninsulated walls will not freeze.

Concerns have been raised by some authorities that interior insulated, poured-concrete basements may show signs of freeze/thaw damage over time. Most poured-concrete basements are formed of pre-mixed concrete blended for strength and freeze/thaw durability. However, once the concrete arrives at the site, it is often watered down to allow for better movement around the forms. When dry, this concrete tends to be high in moisture content and unable to resist freezing action. While there are presently few reports of freeze/thaw damage to poured foundations, the cumulative effect of multiple cycles may be a problem for the future.

3.2.2 Deterioration of Materials

Constant movement of moisture through the basement wall can cause material deterioration. This is usually associated with rubble and clay brick basement construction. It can also be a problem in cast-in-place concrete structures where large amounts of water have been added to the concrete mix prior to pouring. Indicators of a potential problem are; persistently high relative humidity, appearance of efflorescence on the wall surface, spalling of masonry material and crumbling of mortar joints.

Efflorescence on the wall surface occurs when evaporation draws moisture out of the wall. Salts inherent in the building material are leached out and left as residue on the wall. The weakening of the wall due to the leaching out of water-soluble components from brick, mortar or concrete is a very slow process and in most cases will not be very serious.

Spalling and crumbling of basement wall material occurs when evaporative action takes place inside the wall. Salts and minerals, rather than leaching to the wall surface, are left just beneath the surface of the wall or floor. These salts build up pressure and cause surface layers of the wall material to break off or crumble. This type of deterioration is directly related to the type of material and the characteristics of the surrounding soil. In most cases, damproofing the exterior wall face restricts water movement into the walls. However, ground water can still move into walls and the basement floor through the footings.

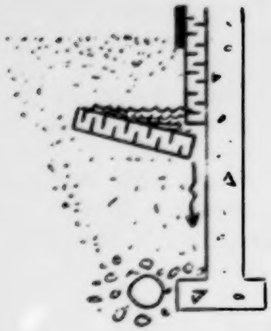
If evaporative action is prevented on the inside wall face through the installation of damproofing and/or insulation, dampness will work up the wall. Evaporative action is likely to occur at the exposed, above-grade portion. This area should be monitored for deterioration.

3.2.3 Capillary Water

Even when well-drained, soil continues to hold moisture as capillary water that clings naturally to the soil particles. If damp soil comes into contact with an untreated concrete or masonry basement wall, moisture can move into the wall.

It is difficult to impede all movement of capillary water into the basement. Good soil drainage around the basement combined with dampproofing of walls in contact with the soil and installation of a moisture barrier below the basement floor will significantly reduce the chances of building component deterioration.

Figure 3.5

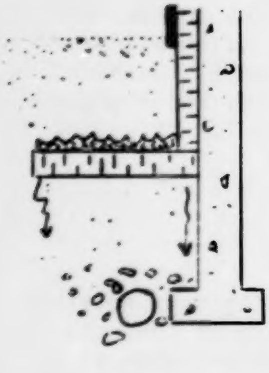


3.2.4 Surface Moisture

Surface water in the form of melting snow or rain should be prevented from penetrating the soil near the house. The perimeter grade should be sloped to ensure positive surface drainage away from the building (1). This is particularly important if a paved driveway or parking area is located next to the building. Eavestrough drainage should also be diverted away from the house using extensions to the downspouts. In many homes, runoff from driveways and downspouts is directed into the drainage system for the footings. Excessive water runoff can overload the drainage system. Abnormally high hydrostatic pressure could build up and cause flooding and possible uplift of the floor slab. Debris carried with runoff water could clog the drainage system and cause a build-up of hydrostatic pressure.

Water damage may also result if drainage of water close to the wall is impeded by a non-porous backfill material such as clay or fine grained soil. Wood scraps and other leftover construction materials can also find their way into backfill, obstructing the downward flow of water. The net result of this obstruction of water movement could be the formation of a standing water table above the footing drain. A steady build-up of water can exert a substantial pressure against the basement wall forcing water through joints or cracks in the wall. Standing water tables can be avoided by ensuring that clean granular type backfill material is used in conjunction with a good foundation drainage system.

Figure 3.6



It is important that exterior insulation be placed so as to direct surface moisture away from the wall. Often exterior foam board is installed below grade in a horizontal or near horizontal position. This approach is an alternative to full excavation and insulation of the foundation wall and can provide protection of the wall and footings against frost action. Under certain circumstances, however, the positioning of the board may direct runoff along the basement wall or result in water build-up above the insulation. Figures 3.5 and 3.6 illustrate how the slope of insulation could affect drainage around the building. In both cases, water runoff may move between the insulating boards and drain down along the wall. It is also possible that build-up of water above the insulation could exert hydrostatic pressure on the wall. Damage to the insulation and the wall are possible if freezing were to occur in this area.

Figure 3.7

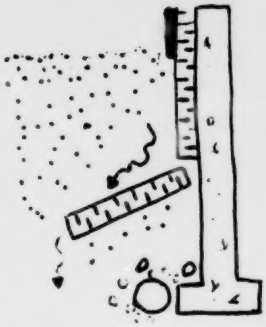
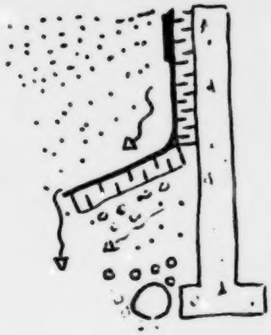


Figure 3.7 shows an installation conducive to good drainage. The use of a polyethylene sheet and granular fill material as shown in Figure 3.8 further ensure that runoff water is directed away from the wall. All of these measures are advisable in a retrofit situation where the nature of backfill material and extent of foundation drainage are unknown.

3.2.5 Condensation

Condensation occurs in a basement area when wall temperatures are at, or below, the dew point temperature for the relative humidity within the basement. The appearance of condensation on the wall and pooling of condensate at the base is often mistaken for direct water leakage. More serious results of the condensation process are the formation of mould and mildew, and the deterioration of wood products in contact with walls and floors.

Figure 3.8

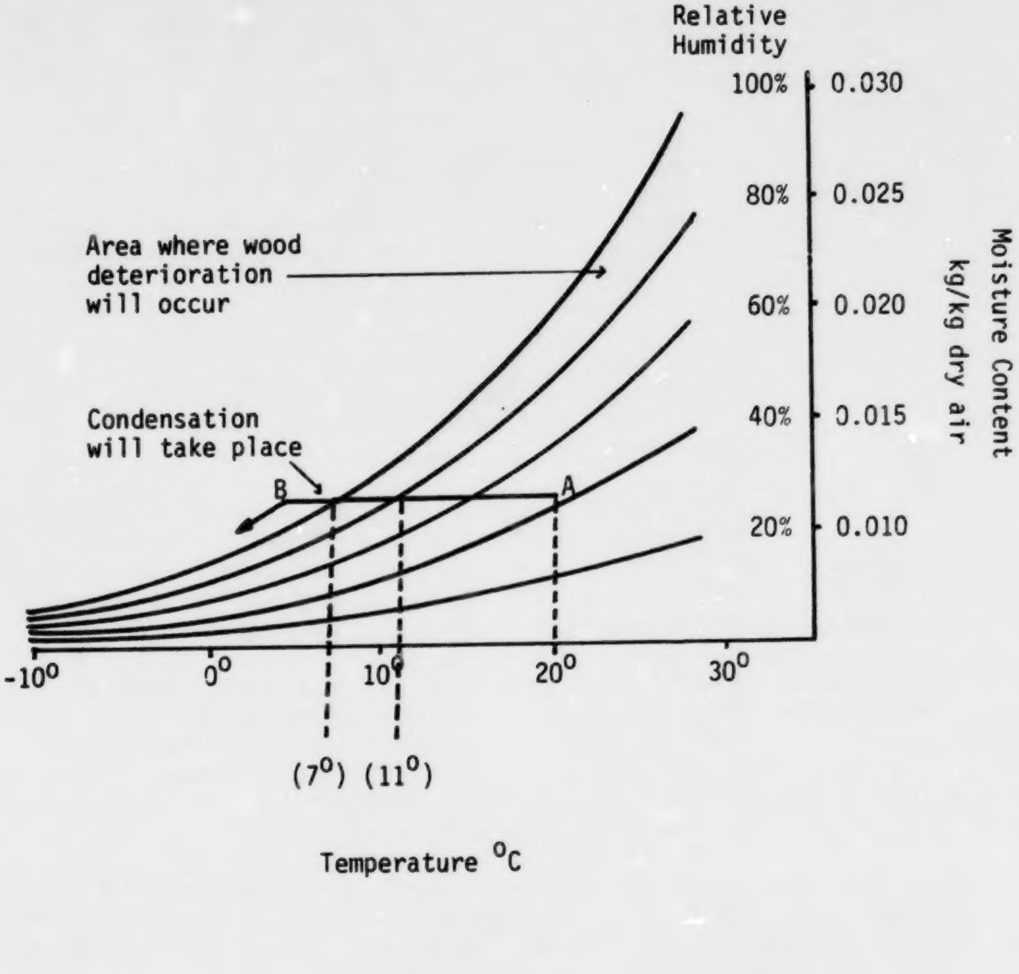


Condensation is most likely to occur in uninsulated basements, basements without a moisture barrier below the floor slab and basements insulated from the interior. Basements properly insulated from the outside are not usually subject to condensation problems.

The moisture content of air at a given temperature is expressed in terms of relative humidity. Relative humidity (RH) is the percentage of moisture in the air in relation to the total amount of moisture the air can hold at a given temperature. An RH of 45 percent at 20°C means that the moisture content of the air is 45 percent of the total moisture that can be held in the air at 20°C. An RH of 100 percent would mean that the air is saturated and cannot hold further moisture. It is at this point that water vapour will condense into water.

Air can hold varying amounts of moisture depending on its temperature. A reduction of air temperature by 9°C will reduce the air's ability to hold moisture by almost half. Figure 3.9 is a psychometric chart that illustrates the relationship between moisture content, temperature and relative humidity. Temperature is plotted along the horizontal axis and moisture content

Figure 3.9 Psychometric Chart



is the vertical axis. Relative humidity is represented by the sloping lines. Point A on the chart represents a basement with a temperature of 20°C and a relative humidity of 45 percent. When the air comes in contact with the cool uninsulated basement wall (Point B: 7°C) air adjacent to the wall is cooled to the point where RH = 100 percent.

At 100 percent RH, moisture will condense on the cold surface. Wood in direct contact with the wall would be subject to deterioration. Condensation need not occur to induce wood rot, relative humidity levels consistently above 80 percent are sufficient. Areas that are subject to cooling and lack of good ventilation such as the header/joist area at the top of the wall may be cooled by the wall enough to induce a high RH and result in deterioration of wooden sills, joists and headers.

This type of deterioration is unlikely to occur in conventional housing located in colder climates. Interior relative humidity tends to be very low, and any moisture will condense and freeze to cold basement walls. In newer, energy-efficient construction, a continuous and well caulked vapour barrier will inhibit movement of moisture to cold areas where wood deterioration could occur.

Condensation can also occur during the summer months. Soil cooled basement walls in contact with high humidity ambient air may lead to wood deterioration. This is particularly relevant in basements ventilated with humid outside air.

To minimize the amount of water that can condense from the basement air during both summer and winter the relative humidity in internally insulated basements should be kept as low as possible. Dryers should be vented outside. If necessary, a dehumidifier should be used during the summer months.

To avoid condensation problems, insulate the exterior of the basement. The basement wall and its connecting components can establish an equilibrium temperature and humidity with the basement air. The moisture content and temperature of the soil ceases to be a critical influence on the basement environment.

3.2.6 Exterior Insulation

Exterior insulation has both advantages and disadvantages with respect to minimizing the risk of moisture damage. Advantages include:

- Since the wall is on the warm side of the insulation, problems associated with cold basement walls - condensation, cracking and wood rot - are generally eliminated.
- If a draining insulation is used, a second line of defence is provided against hydrostatic pressure, water runoff and capillary water movement.
- Thermal bridging through the above-grade exposed face of the wall is eliminated.
- The insulated basement wall can act as a thermal mass, storing heat within the house.
- Stresses resulting from thermal cycling are eliminated since wall temperatures are constant.

The disadvantages of exterior insulation include:

- It may be difficult and costly to install in a retrofit situation due to presence of walks, driveways, porches, and other exterior obstructions. In many cases, sufficient clearance for excavation may not exist.
- Above grade insulation needs a protective coating. Aesthetically, basement insulation carried above grade may be undesirable. In addition, retrofit action in urban areas may be hindered by local by-laws governing building lines and side-lot clearances.

3.2.7 Interior Insulation

High humidity or condensation in the vicinity of wood products in an interior insulated basement may lead to wood deterioration. Relative humidities greater than 80 percent are generally conducive to wood rot. Conditions that can lead to wood deterioration are:

- The lack of or poor vapour barrier installation in conjunction with interior insulation can result in condensation occurring on cold surfaces such as the basement wall. Wood products in contact with or in proximity to these cold surfaces may experience conditions conducive to rotting. All interior insulated walls are likely to experience some frosting and condensation. Water may collect at the wall base.

- Interior insulation inhibits the evaporation of moisture from the foundation wall into the house, and therefore the relative moisture content of the insulated wall section may increase. This moisture is usually absorbed up through the footings. Wood materials directly in contact with the wall (e.g. floor joists) may be subject to condensation and high humidity. Occurrence of this type of deterioration depends on the condition of exterior dampproofing and drainage, soil moisture content and capillary characteristics of the wall.

Condensation and subsequent wood deterioration is unlikely to occur in new construction. In retrofit construction, the header/joist area in masonry or concrete walls, where wood is imbedded in the wall, should be detailed with care and periodically monitored. One authority suggests that insulation of the header/joist area of masonry buildings be avoided until more is known of the possibly consequences. (43)

Wood deterioration can be avoided by:

- the use of pressure treated wood products in suspect areas
- dampproofing of interior walls to grade level with polyethylene or bitumen based material
- mechanical dehumidification of the basement area

Partial exterior insulation over the header area and slightly below grade will eliminate the need to insulate the interior joist space and eliminate the possibility of condensation.

Section 4

Exterior Insulation

4.1 Introduction

Exterior applied insulation must meet the following criteria:

- High compression strength to resist the lateral earth loads imposed by the backfill (138 to 207 kPa is sufficient).
- High resistance to water and very low water absorption so that the RSI value of the insulation is not reduced.
- High resistance to the various chemical properties of soils; therefore, long lived.
- Good dimensional and RSI value stability over a long period of time (approximately 20 years minimum).
- Minimum number of horizontal breaks over depth of wall to reduce cold spots and moisture penetration.

This chapter reviews the materials suitable for exterior basement insulation. Specific details involved in installation and performance characteristics are also included.

There are a number of rigid insulating materials on the market but few meet the criteria described above. The only products currently available in Canada suitable for below grade applications are rigid polystyrene and compacted glass fibre. They are discussed in the following sections.

4.2 Rigid Polystyrene

4.2.1 Types

Four different types of polystyrene insulation are identified by the Canadian General Standards Board (CGSB).* Types I, II, III are expanded beadboard of increasing densities and type IV is extruded polystyrene. Table 4.1 provides the RSI values for the various types.

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*CGSB 41-GP-14a (1972)

Table 4.1 Insulation Values of Polystyrene

	RSI Value per cm	
Type I	0.257	- beadboard of increasing densities
Type II	0.277	
Type III	0.298	
Type IV	0.347	- extruded

Type I, the lowest density beadboard, and also the cheapest polystyrene insulator, is not considered suitable for below grade applications.

Expanded or moulded bead polystyrene foam is made by placing polystyrene beads, containing a blowing agent, into a mold and exposing them to heat. The vapour pressure of the blowing agent causes expansion of the beads producing a predominantly closed cell form. The material is pressed into rigid boards of various densities. Expanded polystyrene is usually white in colour.

Extruded polystyrene foam is manufactured by blowing a hot mixture of polystyrene, solvent and pressurized gas (blowing agent) through a slit into the atmosphere. The reduction in pressure causes the gas to expand producing a foam with a fine closed-cell structure. The blowing agent is usually a fluorocarbon. This material has a considerably higher density than expanded polystyrene and as a result provides greater thermal resistance per centimetre.

Other characteristics of the foam include:

- low water vapour permeability
- high compressive strength
- very low water absorption
- does not sustain mould growth
- lightweight
- has no food value for rodents or vermin
- maintains insulation characteristics over time and extreme weather conditions

4.2.2 Performance

Comparative testing of different polystyrene materials and other cellular plastic foams indicates that extruded polystyrene best maintains its thermal integrity over time when subjected to below-grade moisture and soil pressures.

Table 4.2 shows the results of independently verified testing of various foam insulating materials. The materials were buried and recovered at two locations: Sarnia, Ontario and Granville, Ohio. Before and after measurements for thermal resistance and moisture content were compared. As shown, the extruded polystyrene was least affected by soil conditions.

Table 4.2 Thermal Resistance Loss (%) of Various Foam Plastic Insulations After 6 and 18 Months of Soil Exposure

Material	Thermal Resistance Loss (%)	
	6 Months	18 Months
Extruded Polystyrene (Unfaced)	1	2
Beadboard (Unfaced)	7	25
Polyurethane (Unfaced)	14	15
Polyurethane (Faced)	7	15
Polyisocyanurate (Faced)	23	36

SOURCE: "Thermal Performance of Various Insulations In Below-Earth-Grade Perimeter Applications", Ovstass et.al. Presented at the DOE-ORNL/ ASTM C-16 Symposium on Thermal Insulations, Materials, and Systems for Energy Conservation in the 80's.

Other results of this study indicate that:

- as water content increases, the thermal resistance of a material decreases
- as exposure duration increases so does moisture content
- thin samples tend to absorb more water
- horizontal samples absorbed more moisture

4.3 Glass Fibre Insulation

Fibre type insulation material acts as both an insulator and as a drainage membrane when installed on the external face of a basement wall. The insulation in panel form is usually produced from mineral or glass wool. The only material currently available in Canada is a glass based product which is produced by melting down glass marbles. The molten substance is spun into fibres which are sprayed with a phenolic resin. The fibres are compressed into a rigid board, with the resin serving as a binder, and cured in an oven.

In the manufacturing process, the glass fibres are layered in the plane of the board. As a result, when installed vertically, ground water coming in contact with the board is drained downward along the fibre plane. Lateral movement of water to the basement wall cannot occur. Due to the density of the fibre material, only a few millimetres of the board actually acts as a drainage medium. The remaining thickness of the board acts as an insulator.

Glass fibre boards for exterior below grade application have densities of 50 kg/m^3 or greater. Currently, only one glass fibre board (Baseclad) suitable for below grade application is marketed in Canada. Board dimensions are 120 cm x 244 cm x 5 cm. It is considered to have an RSI value of 1.5.

Performance testing of exterior mounted compacted fibre insulation has been carried out in Scandinavia where the material has been in use for more than ten years (16,17). Its use in the past has been primarily as an exterior drainage layer. However, rising energy costs have stimulated interest in this product as an insulator as well.

Glass fibre insulations are not susceptible to fungi, bacteria or mildew attach from the soil. It also is an effective capillary break, and provides an unobstructed route for water to drain to the footing. The surface in contact with the soil acts as a drainage layer while the remainder of the insulation remains dry. As a result, the insulation is not subjected to the degrading effects of moisture. Glass fibre insulation, therefore, retains its thermal characteristics, and is unaffected by soil pressures and excessive moisture levels. In tests done on houses ranging in age from one to four years, with soil moisture content varying from 7 to 30 percent, it was found that the moisture content of the mineral wool insulation remained low; usually less than one percent (17,49).

Tests by the National Research Council in Saskatoon indicate that the thermal resistance of fibre insulation is reduced when the material must handle large quantities of cold water runoff (e.g., in the spring). This is due to the heat in the insulation being drained away by the cold water flowing through it. The effect is temporary and does not imply deterioration of the material. Some soil enters the immediate surface layers of the insulation, but none of the test cases showed that the insulation had been infiltrated by soil.*

Drainage-type insulation has also been formulated with mineral wool products. While no such products presently exist in Caanda, they have been used extensively in Sweden and tested on a limited basis by the National Research Council of Canada (16,17,49).

4.4 Installation

Various aspects of the installation process apply to the use of both rigid foam and glass-fibre insulation. These include wall preparation, dampproofing and the protection of above-grade material.

4.4.1 Wall Preparation

If the wall to be insulated is ineven, it should be parged to provide an even surface for applying the insulation and prevent convective air currents behind the insulation. The wall should also be dampproofed if moisture penetration is expected to be a problem. If, after parging and dampproofing, the wall is still uneven, further measures must be taken to reduce convective air movement. Coarse grained sand poured between the insulation and wall will eliminate air movement. This should be done after backfilling. An alternative approach is to caulk the wall in a grid pattern before installation of the insulation to isolate air pockets.

For a secure bond, old dampproofing material should be removed from the wall before parging takes place. Many dampproofing materials may contain solvents that can cause degradation of the foam insulation. Due to the concentration of solvents, trowelled on coatings should be allowed to cure until dry to the touch. Spray coatings, applied in thin layers, have lower solvent concentrations and permit installation of the foam soon after dampproofing. Dampproofing should never be used as "tack" coat to attach insulation to the wall.

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*Discussion with Harold Orr, National Research Council Canada, Division of Building Research

4.4.2 Dampproofing

Although dampproofing is required by section 13 of Residential Standards (1), testing in Scandinavia has shown that the elimination of the exterior dampproofing coat results in a drier basement wall. The relatively impermeable bituminous material used for dampproofing hinders the escape of moisture (16,17.49).

Nevertheless, most Canadian building codes require that all exterior basement walls be dampproofed below grade, as shown in Figure 4.1. A concrete cant strip, running from a point 50 cm above the footing with a 1:2 slope and a polyethylene layer on top, can provide additional protection to the wall where water build-up can occur.

Because of slight differences in the installation process, rigid foam insulation and fibre insulation are dealt with separately. The following section deals with rigid foam insulation.

4.4.3 Rigid Foam Installation

The HUDAC technical committee involved in research and field testing of exterior insulation of basement walls recommends that rigid foam insulation boards should be installed in sheets 15 cm longer than the height of the area to be insulated, and cut to fit at the top after installation and backfilling have been completed. This technique eliminates the worry about the fit at the top of the wall and provides a safety margin in case the insulation is pulled down with the backfill (25).

In both retrofit and new construction, mechanical fasteners will effectively adhere the foam board to the wall. Driving galvanized common or concrete nails into pre-drilled holes fitted with nylon expansion shields was considered the most successful method in a series of tests conducted by HUDAC (25). Mastic adhesive coatings are not recommended. The use of pressure treated wood nailing strips cast-in-place during construction of concrete basement walls is also effective. Nailing strips should be no larger than 38 x 38 mm. Larger strips can swell and cause cracking of the concrete.

Figure 4.1

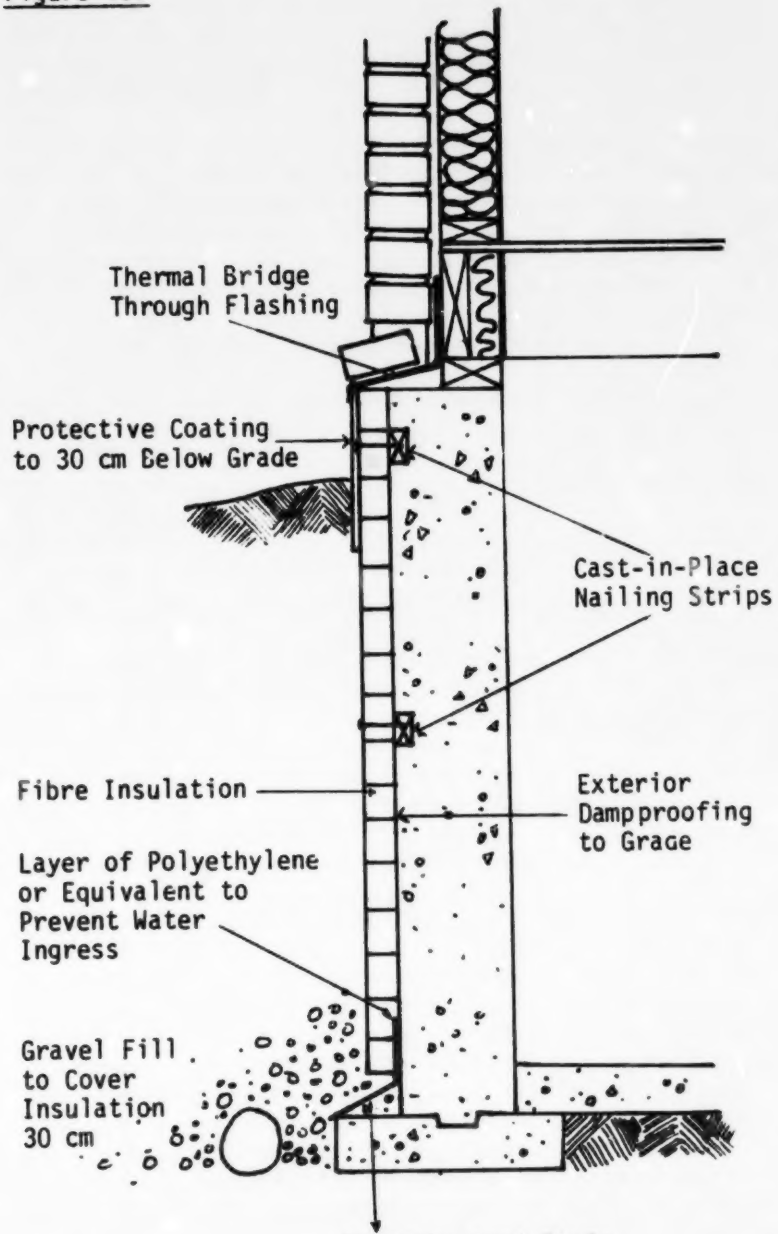
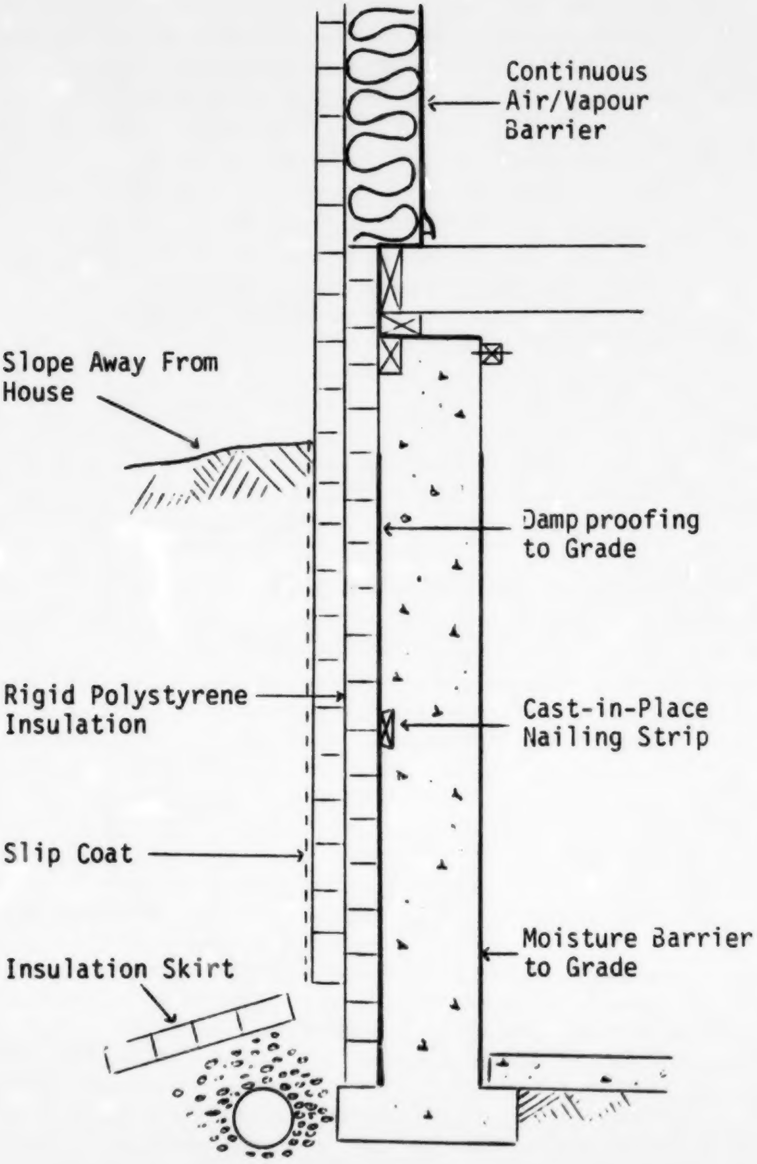

Thermal Bridge
Through Flashing
Protective Coating
to 30 cm Below Grade
Cast-in-Place
Nailing Strips
Fibre Insulation
Exterior
Dampproofing
to Grade
Layer of Polyethylene
or Equivalent to
Prevent Water
Ingress
Gravel Fill
to Cover
Insulation
30 cm
Concrete Cant Strip

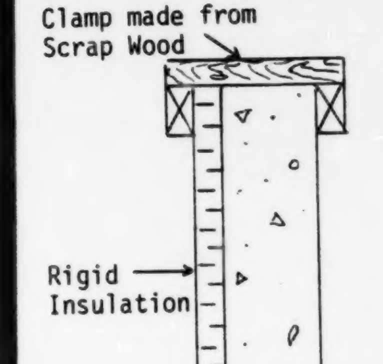
Figure 4.2


Continuous
Air/Vapour
Barrier
Slope Away From
House
Damp proofing
to Grade
Rigid Polystyrene
Insulation
Cast-in-Place
Nailing Strip
Slip Coat
Moisture Barrier
to Grade
Insulation Skirt

The boards can be held in place at the base of the foundation by placing gravel against the bottom of the boards. This also ensures good drainage from the surface of the insulation to the weeping tiles or gravel drainage pad.

Rigid foam insulation applied in an almost horizontal position will provide frost protection for foundation footings and weeping tiles. For this purpose, insulation is placed at a 20° angle sloping away from the basement wall. The foam boards should be a minimum of 70 cm long and should extend around the perimeter of the footings. Figure 4.2 details a typical exterior insulating approach with frost protection.

Figure 4.3



Horizontal insulation is also used in conjunction with partial below grade insulation. An advantage to this approach is that excavation to footing level is not required. However, this is not as effective as full wall insulation.

4.4.4 Glass-Fibre Installation

The compacted fibre insulation boards are applied after damproofing of the basement wall is complete. The boards are placed vertically with each board butted tightly to the next. The recommended installation method is to start at one corner of the basement and keep working in one direction. The boards should cover the full height of the wall. Horizontal joints may impede the downward flow of moisture.

During installation, the boards are held in place by gravel at the basement wall footings. A clamp made up of scrap wood can temporarily hold the top of the board until backfilling takes place. See Figure 4.3. Mechanical wall fasteners are used to attach the mid-portion of the board to the wall. For concrete basement walls, a cast-in-place wood nailing strip can simplify attachment at the mid-point and top of the wall. Tests conducted by the Housing and Urban Development Association of Canada indicate that adhesives do not adequately bond the board to the wall (25).

It is very important that prior to backfilling at least 30 cm of gravel be placed against the insulation base to provide a drainage path to the weeping tile or drainage gravel pad. If this detail is not adhered to, hydrostatic pressure can develop at the footing level.

The above grade portion of the insulation will have to be capped and covered with a protective coating (1). Protective coatings include asbestos board, treated plywood and galvanized expanded metal lath with a parge coating. This protection should extend 30 cm below grade. The top of the insulation should be capped and flashed to prevent water penetration.

Figure 4.1 illustrates various aspects of the installation process discussed here. It also shows the bridging effect through the flashing detail. This is a result of combining conventional design practice with current thermal upgrading requirements. A thermal break is relatively easy to achieve but requires a change in thinking on the part of the building trades.

4.4.5 Above Grade Protection

The primary concerns here include the exposure of the raw or edge face of the material to the elements and the thermal bridging from installation procedures.

Both fibre and rigid foam insulation must be protected from damage (1). Polystyrene must be protected from ultraviolet light and fire. Protection of the insulating board above grade is accomplished by installing metal flashing over the top edge of the insulation and parging the exterior face of the insulation. Parging should be done after backfilling and sodding has been completed so that the finish will not be damaged by equipment during construction. The sod can then be pulled back from the wall to permit application of the wall finish (25).

The most common parging material is masonry-portland cement applied to a galvanized metal lath or directly to the insulation. However, direct application of parging to the insulation is not always reliable. A new fibre-reinforced-polymer modified portland cement which will form a bond with all foam insulating materials is available. This material can control cracking without the need for a metal lath. but it is expensive. Pre-finished expanded polystyrene and pre-finished metal lath reinforced composite on polyurethane are also available. They are easily damaged on the site and are not recommended because of poor freeze-thaw characteristics.

Table 4.3 Results of Impact and Freeze/Thaw Resistance Testing

Insulating Board and Protective Cover	Coating Thickness (mm)	Impact (Newton Metres)	Freeze/ Thaw
Extruded Polystyrene Type IV			
A	7 - 13	17+ p	p
B	7 - 13	13.6 p	p
C	5 - 11	6.8 p	p
D	5 - 11	7.9 p	p
F	5	4.0 f	*
Expanded Polystyrene Type I			
A	7 - 13	17+ p	p
B	7 - 13	15.8 p	p
C	5 - 11	4.0	f
D	5 - 11	7.0 p	p
F	5	2.7 f	*
Glass Fibre 70 kg/m^3			
A	7 - 13	17+ p	p
C	5 - 11	6.8 p	p
D	5 - 11	5.7 to 6.8 p	p
Glass Fibre 50 kg/m^3			
D	5 - 11	10.2 p	p

p = passed test   f = failed test   * = not tested

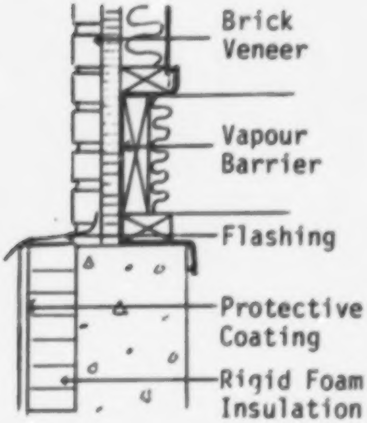
Protecting Coatings

A Proprietary -- polymer-modified -- glass fibre -- portland cement -- admixtures
B Proprietary -- glass fibre -- portland cement -- admixtures
C Proprietary -- glass fibre -- unknown composition
D Parging -- masonry : portland cement : sand - 7:2:23 by volume
E Proprietary -- cementitious with steel mesh -- prefabricated in plant (results withheld by request)
F Proprietary -- composition unknown -- prefabricated in plant

Source: HUDAC, External Insulation of Basement Walls Phase II Report, September, 1981.

HUDAC has conducted a number of tests on the impact resistance and freeze/thaw characteristics of various protective coatings (25). Table 4.3 summarizes the results. Materials that could sustain an impact of 4.5 Newton-metres (N-m) or greater deemed past the test. Standards for the resistance of protective coatings do not presently exist so that the test method for impact resistance of Pipeline Coatings ASTMG14-77 was used. Type I polystyrene was tested despite its unsuitability as a basement insulator in order to determine if density of the base material had any effect. Major findings indicate that the thickness of the coating has a direct bearing on impact resistance. It is recommended that applied protective coatings be a minimum of 1 mm thick.

Figure 4.4



All samples that passed impact testing were subjected to 50 freeze/thaw cycles. The testing procedures is a modified version of the Canadian Standards Code for Testing Brick (CAN3-182.2-M78). All materials passed the test, including Type I polystyrene, which is considered unsuitable for below grade applications.

Other materials suitable for exterior protection include cement asbestos board, pressure treated plywood, rigid vinyl sheeting, aluminum sheeting and painted metal facing. This material can be mechanically fastened or nailed into place, utilizing the sill plate and, where applicable, cast-in-place nailing strips. Aluminum sheeting and metal facing should terminate at ground level, all other materials should extend 30 cm below grade.

Figure 4.5

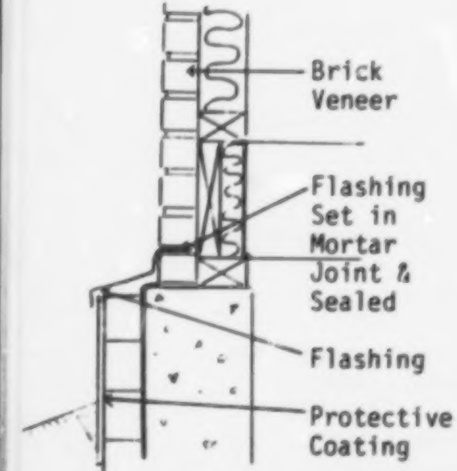


Figure 4.4 illustrates the method of application commonly used with a brick veneer. A flashing strip is necessary to seal the top of the insulation and is embedded into the mortar. Possible thermal bridging can occur from the base of the veneer to the concrete wall. The detail accommodates conventional building practice rather than complete thermal efficiency.

Figure 4.5 illustrates a similar approach in retrofit applications. Note that the flashing is inset into the mortar joint and caulked. Mechanical fastening of the flashing will be necessary. Thermal bridging through the veneer can be reduced by carrying the insulation 30 cm above the level of the header. Further insulation of the header area from the exterior will reduce the possibility of wood deterioration.

Figure 4.6

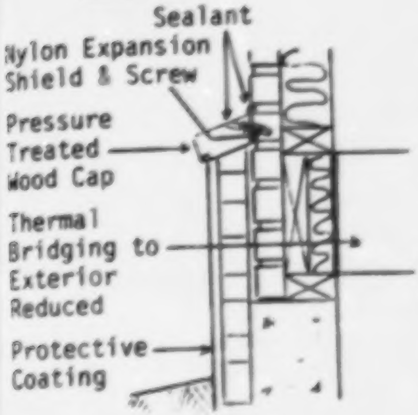
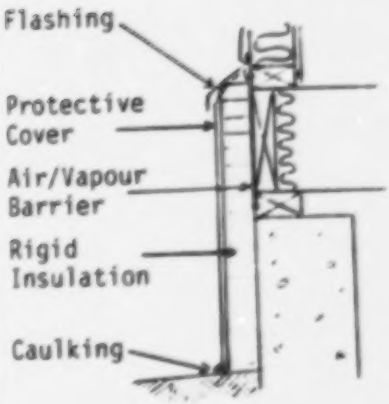

Sealant
Nylon Expansion Shield & Screw
Pressure Treated Wood Cap
Thermal Bridging to Exterior Reduced
Protective Coating

Figure 4.6 shows a variation of the above approach developed by John Timusk of the University of Toronto which used a trimmed two-by-four of pressure treated wood. Nylon expansion shields and rust resistant screws anchored into the brick hold the cap in place. The cap is caulked at the wall and at the countersink holes for the fastening screws. This detail utilizes materials and skills that can be easily applied by a homeowner (48).

4.5 Additional Insulation Details

4.5.1 Partial Exterior Insulation

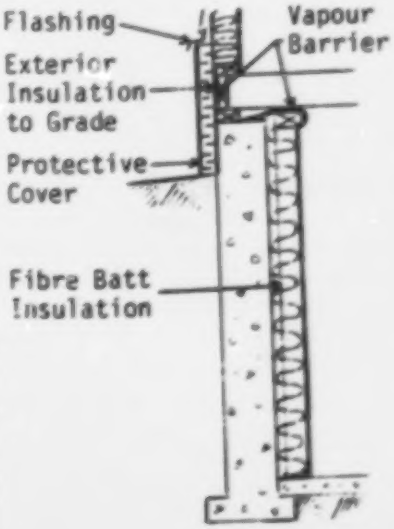
Figure 4.7


Flashing
Protective Cover
Air/Vapour Barrier
Rigid Insulation
Caulking

For many existing homes, excavation around the perimeter of the house, even to partial depth, may not be feasible due to the presence of walkways, patios, etc. However, exterior insulation can be installed above grade to reduce thermal bridging and thermal stresses on the exposed basement wall. Figure 4.7 shows the installation details of this approach. Because this application is completely above grade, rigid insulating materials other than polystyrene can be used. The insulation is fastened to the wall with mechanical fasteners. A protective coating should be installed over the insulation and it should be capped and flashed at the top. A bead of sealant placed between the bottom of the protective cover and the pavement will impede water penetration to the wall and act as an expansion/contraction joint.

For best results, the insulation should extend above the header joist area. A sheet of polyethylene placed between the header area and the insulation will act as a vapour barrier. Any additional interior insulation should not exceed half the RSI value of the exterior insulation. Where applicable, insulation can be carried below grade. Fibre insulation, however, is not suitable as a below grade insulator unless connected to the foundation drainage system.

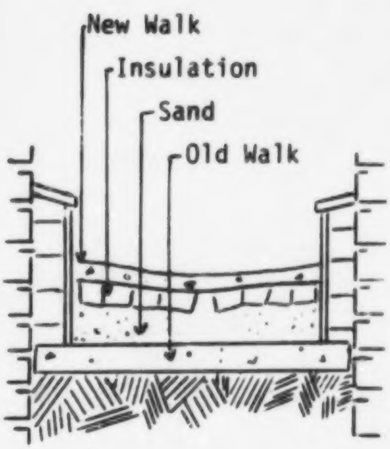
Figure 4.8


Flashing
Vapour Barrier
Exterior Insulation to Grade
Protective Cover
Fibre Batt Insulation

4.5.2 Partial External/Internal Insulation

The previously discussed detail can effectively be used with internal insulation. Thermal bridging and freeze/thaw damage can be significantly reduced. By insulating the outside of the header area, the condensation problems associated with internal insulation can be avoided. Figure 4.8 illustrates a combined internal/external approach.

Figure 4.9

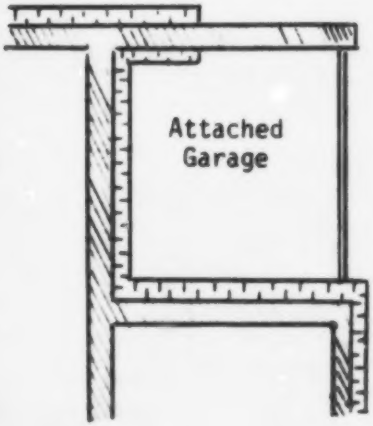


4.5.3 Insulating Common Walkways

In older residential districts, homes may be built so close together that excavation for external insulation is not possible. In some cases, homes may share a common wall below grade to qualify as semi-detached yet above grade they will appear to be detached. In both these cases, the approach used in Figure 4.9 illustrates a good treatment of this common space.

Walls are insulated vertically from grade level to the desired height (exterior insulation should at least cover the header area). Insulation is then placed on a sand base along the length of the wall. The sand is placed to allow for a positive slope for drainage the length of the wall. Insulation slopes to the centre to provide a gutter for runoff. A layer of polyethylene is laid over the insulation before the slab is poured.

Figure 4.10



4.5.4 Garages and Other Cold Wall Extensions

In new construction a foundation wall often carries into a section of wall that does not require insulation (e.g., a garage foundation). When a basement wall is insulated on the exterior face, insulation should continue past the warm/cold junction of the wall for at least another 60 cm as shown in Figure 4.10.

As heat losses from the basement are reduced by increased insulation, the chance of heave, adfreezing, and uplift damage occurring to the attached uninsulated structure is increased. The Ontario Home Warranty Program has already had a number of complaints of such occurrences. Although part of the problem has been identified as poor soil drainage, consideration of minimal insulation of cold walls to protect against freeze damage may be worthwhile.

4.5.5 Basement Floor Insulation

Experience to date indicates that insulated slabs lead to drier basements. In new construction, it is possible to insulate below the basement slab before the pour is made. Rigid polystyrene placed below the slab acts as both an insulator and a moisture barrier. While conventional polyethylene moisture barriers are often destroyed during the pour, rigid insulation provides greater resistance to damage.

Figure 4.11

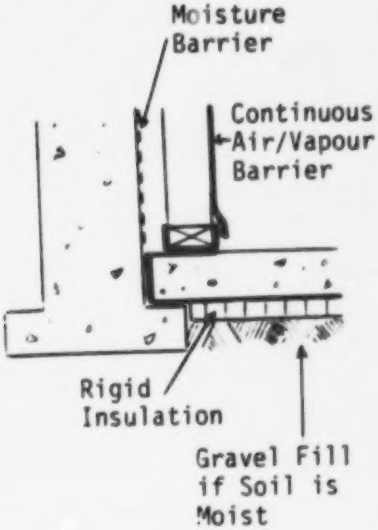


Figure 4.11 illustrates one approach to insulating below the slab using a polyethylene moisture barrier in conjunction with rigid insulation. A polyethylene moisture barrier is still required in basements that are to be finished or are built on moist soils (2). Though often irreparably damaged during construction, the barrier can be lapped around the slab and caulked at the bottom of interior frame wall. This detail ensures a continuous vapour barrier envelope around the basement area. Capillary movement of water up through the footings and into the slab is also inhibited.

In areas with moist soils or high water tables, a layer of compacted gravel should be placed below the insulation (2). Excavation should not go below the level of the footings.

The economic aspects of basement floor insulation are not yet clear. The structural effect of placing a good moisture barrier under the slab has also not been resolved. Reducing heat loss from the floor slab may also increase the chances of frost penetration to the footings or below the floor area. Heaving or uplift may result.

4.6 Summary

There are currently only two insulation materials available in Canada that are suitable for use in direct contact with the soil. Extruded polystyrene is the most commonly used, while rigid glass fibre has been tested in Scandinavia and is now in use in Canada. A similar material made of rock wool may be available in the near future.

Many of the advantages of using glass fibre insulation are similar to those for polystyrene. Glass fibre applied to the exterior face of the basement wall adds thermal mass. The wall remains at an almost constant temperature, close to room temperature, making the basement more comfortable. The risk of condensation is reduced because the walls are warmer. The exterior face of the wall is protected from chemical degradation by the soil.

Glass fibre insulation performs two functions: it breaks capillary action between the soil and the wall by providing a drainage layer for the moisture, and it acts as an insulating layer. Hence, it offers some advantages over other exterior insulations.

It should be noted that because of the improved drainage action, greater demands may be placed on the perimeter weeping tile system. Care should be taken to ensure that only ground water will come into contact with the fibre insulation. Surface water should be drained away from the house by means of positive grading.

Other advantages include:

- Glass wool insulation has a high resistance to chemicals in the soil. These chemicals which are carried by the moisture can only penetrate the outer layer of the mineral wool, leaving the largest portion of the board untouched.
- The need for granular fill when backfilling is greatly reduced due to the drainage qualities of the mineral wool insulation. However, a good drainage path from the insulation to the weeping tile system (using granular fill) is essential.
- Concrete walls dry faster with lower moisture levels and thus better insulation levels. Especially when the Scandinavian approach to damproofing is used.

All exterior insulation must be protected above grade and positively fastened to the wall. Mechanical fasteners or wood nailing strips cast into the basement wall work best.

If case-in-place nailing strips are used, they should be no larger than 38 x 38 mm. Larger nailing strips can swell and cause cracking of the concrete wall. The use of adhesives is not recommended. There are a wide range of materials that can be used to provide above grade protection to the insulation.

The advantages to exterior insulation are summarized as follows:

- Exterior insulation can be installed to the outside wall of new housing just before backfilling.
- In retrofit situations requiring exterior waterproofing or the inspection/installation of footing drains, it can be easily installed.
- Thermal bridging through the above grade exposed face of the wall is eliminated.
- Because wall is on warm side of the insulation, problems assocaited with cold basement wall, condensation, cracking and wood rot, are eliminated. The wall remains at a nearly constant temperature year round.

- The insulation acts as a protective cushion for the basement wall against vertical heave and lateral movement of soil.
- If an exterior applied draining insulation is used, a second line of defence is provided to the basement wall against hydrostatic pressure, water runoff and capillary water movement.
- The insulated basement wall acts as a thermal mass, retaining heat within the house.

Disadvantages of exterior insulation include:

- It may be difficult and costly to install in a retrofit situation due to presence of walks, driveways, porches and other exterior obstructions. In many cases, sufficient clearance for excavation may not exist.
- In areas of adfreezing or expansive clays, the insulation may move with the soil. Thermal performance of the insulation may be reduced as a result of damage or movement away from the wall.
- Above grade insulation needs a protective coating.
- Aesthetically, basement insulation carried above grade may be undesirable. In addition, retrofit action in urban areas may be hindered by setback requirements.

Section 5

Interior Insulation

5.1 Introduction

Interior applied insulation must meet the following criteria:

- Protected from fire if flammable
- Good dimensional and RSI-value stability must be maintained over an extended period of time (approximately 20 years minimum)
- Non-toxic
- Low cost, presently available and easily handled
- High RSI-value per cm of thickness to minimize interior space losses
- Resistant to deterioration due to moisture or high humidity

There are a wide range of materials that can meet these criteria, including those products previously discussed as exterior insulation material. Table 5.1 lists these materials and their respective RSI-values.

Table 5.1 Interior Basement Insulation Materials

		RSI
Batt		
Mineral Wool & Glass Fibre		.208
Rigid Board		
Polystyrene:	Type I	.257
	Type II	.277
	Type III	.298
	Type IV	.347
Urethane or Isocyanurate Board		.420
Rigid Glass Fibre		.277

Batt insulation made of mineral or glass wool is non-flammable. When installed it must be incorporated with some sort of frame support, usually a wood stud wall.

Rigid board materials, with the exception of glass fibre are flammable and produce toxic fumes when burned. They must be covered by a fire resistant material such as 13 mm gypsum board (1).

Because cellular plastic is not subject to deterioration in moist environments when affixed directly to a basement wall, dampproofing is unnecessary.

5.2 Installation

5.2.1 Dampproofing

The inside face of the concrete foundation wall should be dampproofed where wood products, or insulation materials other than cellular plastic types are placed on or near the wall (12). The dampproofing will force water vapour trapped within the insulation to disburse. As illustrated in Figure 5.1 the dampproofing should extend from the footing to a point level with the exterior grade surface.

The most common dampproofing materials are bituminous coatings, asphalt impregnated felt building paper and polyethylene sheets. Some concern has been expressed about the use of polyethylene sheets. It is thought that the polyethylene (carried as a continuous sheet from the warm side of the insulation, under the bottom wall plate, and up to ground level), may trap water vapour in the insulation. Thermal performance is reduced and wood deterioration can result.

5.2.2 Vapour Barrier

An airtight vapour barrier, preferably 6 mil polyethylene, is placed over the insulation and framing. Polyethylene sheets should overlap at least 15 cm and should be caulked with an acoustical type sealant or taped. If tape is used it should be specifically designed for this application. Special care should be taken to ensure air-tight bonding of the tape and polyethylene. All staples should also be caulked or taped over.

Plumbing inlets and outlets and plumbing stacks should all be sealed to the vapour barrier. Significant holes or gaps can be sealed with compressed oakum. Plumbing can freeze if located in the insulation close to the outside wall. It is therefore highly advisable that plumbing be located or relocated away from exterior walls. Plumbing that must be located in an insulated wall should be positioned on the warm side of the insulation.

The location of electrical outlets and switches on outside walls should be avoided if possible. They are difficult to seal properly and can be major sources of air leakage.

Figure 5.1

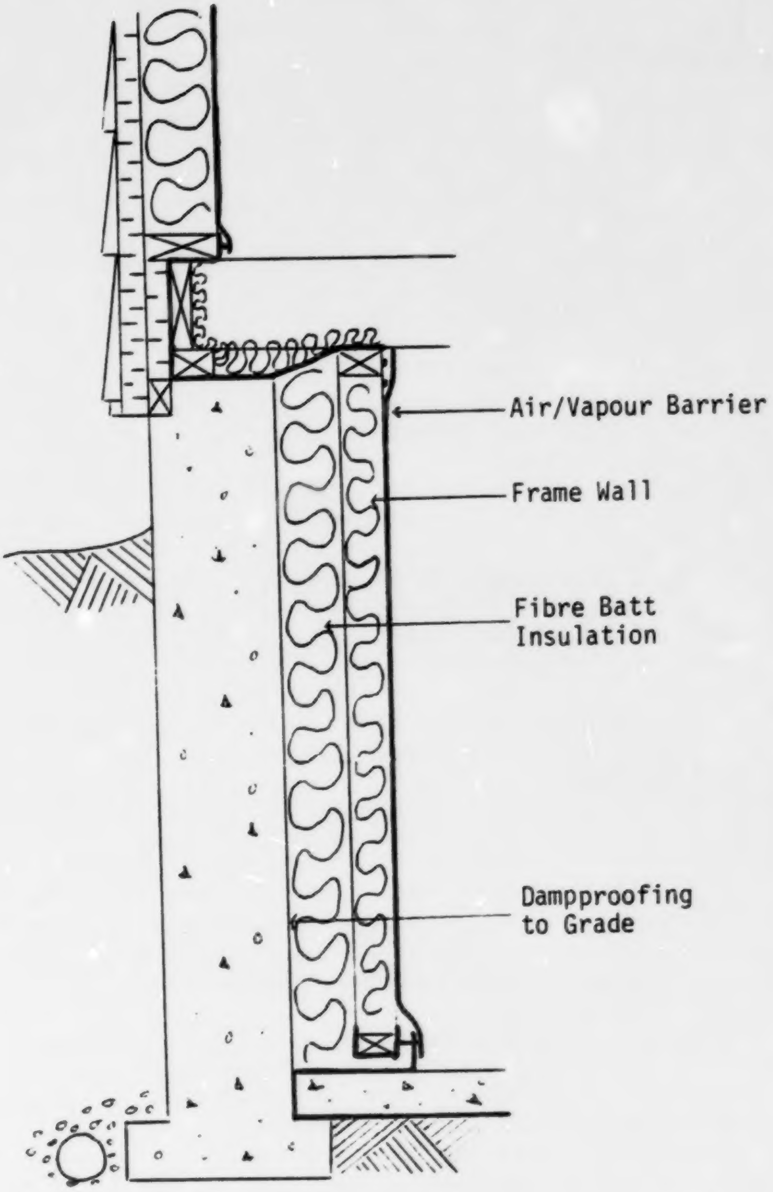
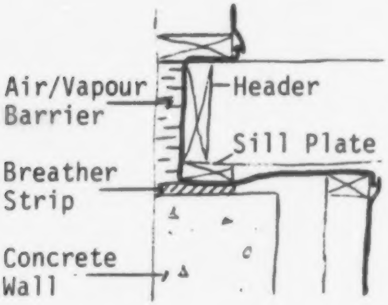

Air/Vapour Barrier
Frame Wall
Fibre Batt
Insulation
Dampproofing
to Grade

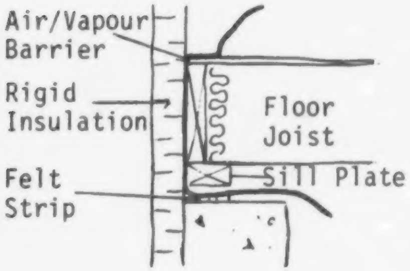
Figure 5.2



In existing houses the main electrical service is often mounted on a plywood panel attached directly to the foundation wall. If the wall is to be insulated, the panel should be moved to ensure that a continuous application of insulation and vapour barrier exists behind the panel. In addition, the area around the electrical conduit entrance to the house should be well caulked and sealed.

Air vents for clothes dryers, heat exchangers, solid fuel burning applicances and oil and gas appliances should also be sealed to the vapour barrier. A strip of polyethylene can be caulked to the vent and subsequently to the vapour barrier.

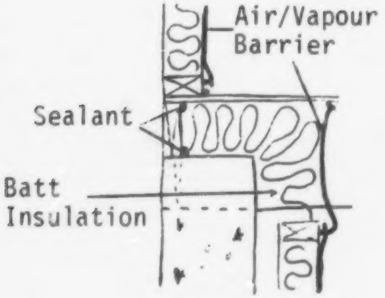
Figure 5.3



The vapour barrier should not be sealed to the frame walls until the concrete wall has had time to fully cure. The minimum curing period is considered to be about six months. If the interior must be finished immediately, a grooved breather strip may be installed beneath the sill plate as shown to allow moisture to escape (Figure 5.2).

In new construction, the vapour barrier should be wrapped around the outside of the header and sill plate. A felt pad can be placed under the sill plate to prevent damage to the vapour barrier. As shown in Figure 5.3, additional fibre insulation may be added to the warm side of the vapour barrier as long as its RSI-value is less than half the exterior RSI-value. Too much insulation placed on the interior will result in condensation and possible deterioration of header, sill and joists.

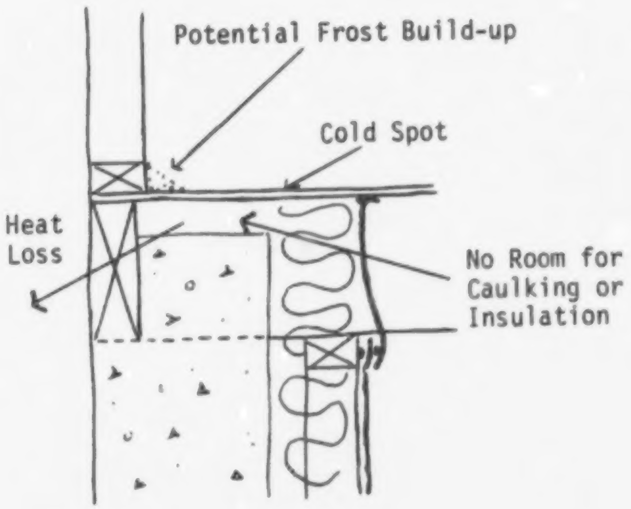
Figure 5.4



In retrofit applications, all joints and cracks should be caulked to eliminate air infiltration before the insulation is installed. Figure 5.4 shows the typical installation of batt type insulation for a cast-in-place header. Although it is a difficult task, the perimeter of the vapour barrier should be sealed and caulked between the joists.

In some situations the space between the top of the basement wall and the upper subfloor does not allow enough room for insulation to be added. If the rest of the basement wall is insulated and sealed the space at the top of the wall can become a thermal bridge creating a cold spot on the floor above. Heat loss, air infiltration and possible frost build-up can result as shown in Figure 5.5. Exterior application of insulation at least from ground level to above the header area would eliminate this problem.

Figure 5.5



5.2.3 Rigid Foam Installation

Foam insulation is attached to the basement wall by means of wood strapping protected by wrapping or backing the wood members with polyethylene. Alternatively, preservative treated strapping can be used (1). As shown in Figure 5.6, a bead of sealant is placed beneath all strapping at the base of the insulation, or the edge of the strapping is caulked to discourage air movement behind the insulation. This is done whether the insulation is applied to the full height of the basement wall or only from the header to just below grade.

The wood strapping is generally placed vertically 40 cm apart with a nailing strip at the top and bottom of the wall. Because of the highly flammable nature of foam insulation it is necessary to protect the foam from fire. The minimum protection according to the National Building Code is 13 mm gypsum board (1). The gypsum board is fastened to the strapping using conventional drywall screws. The gypsum board can also be fastened directly to the insulation with a mastic type adhesive. However, a wood nailer strip should be maintained at the top and bottom of the wall to provide mechanical attachment.

Figure 5.6

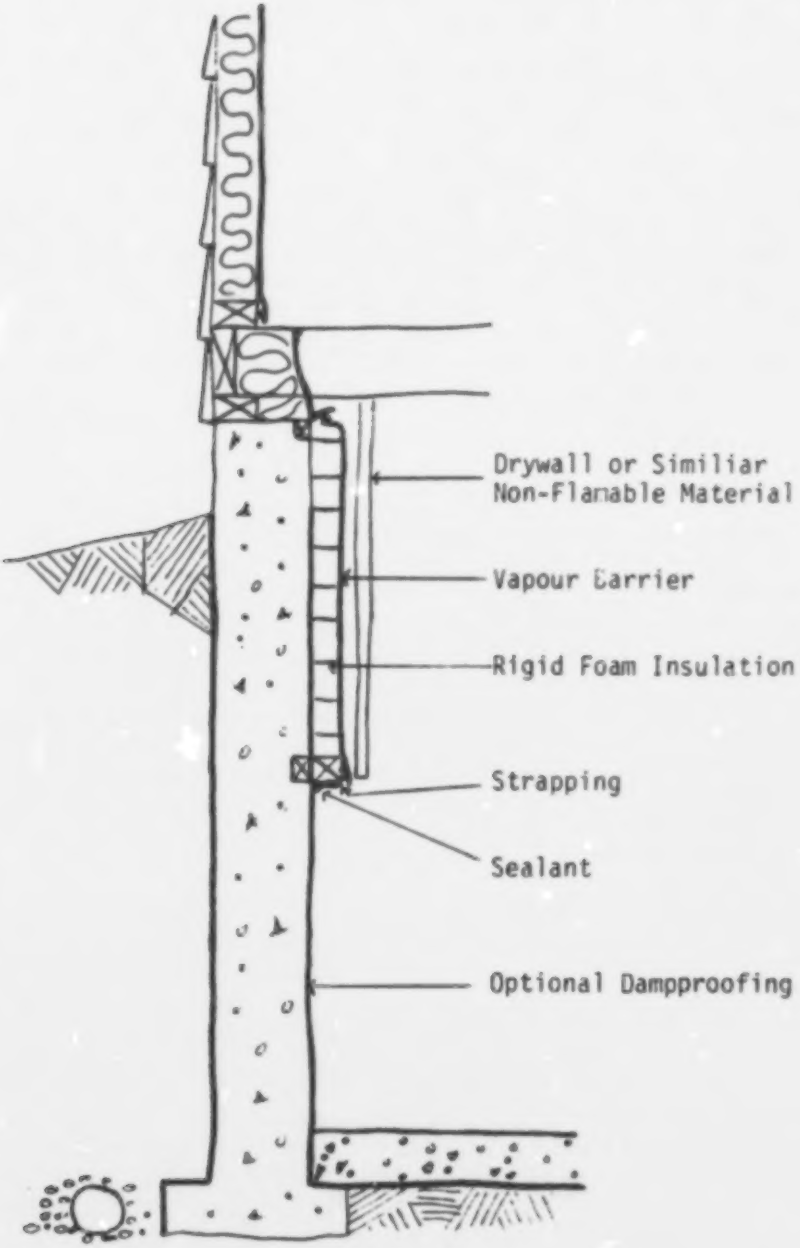
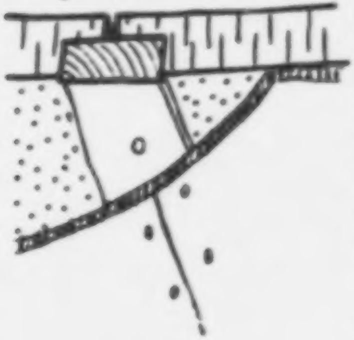
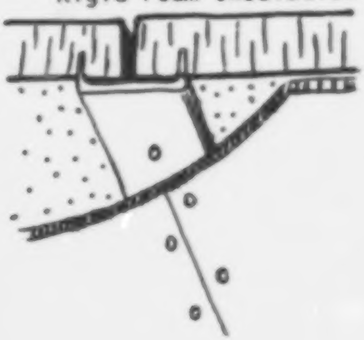

Drywall or Similiar
Non-Flamable Material
Vapour Carrier
Rigid Foam Insulation
Strapping
Sealant
Optional Dampproofing

Figure 5.7



Wood strapping, when fastened directly to the wall, creates a thermal bridge which reduces the thermal effectiveness of the insulation. Applying the wood strapping as shown in Figure 5.7 reduces this problem. A proprietary metal strapping system can also be used to eliminate the bridging problem. The insulation is placed against the wall and held in place with metal strapping fitted into slits in the foam and anchored to the wall using screws or nails. The drywall is then fastened to the metal strapping using conventional drywall screws (Figure 5.7A). Both vapour barrier and caulking are still required on the warm side of the insulation.

Figure 5.7A



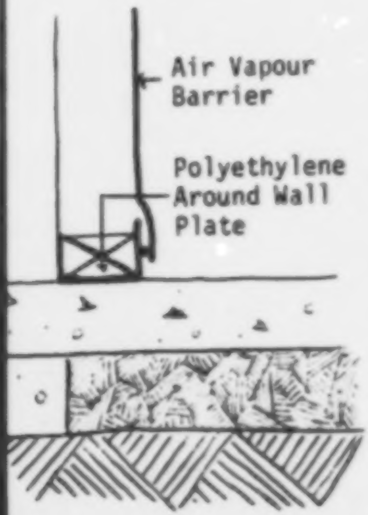
5.2.4 Batt Insulation

Batt insulation is incorporated in a framewall usually constructed of 38 x 89 mm studs placed on 600 mm centres or 38 x 38mm wood studs placed on 400 mm centres. The framewall is usually prefabricated and erected in sections. A 30 cm strip of polyethylene wrapped around the bottom plate will protect it from moisture through the basement floor. If wood is butted to any concrete exterior surface, it should be protected by a polyethylene membrane (see Figure 5.8). As a better alternative, pressure treated wood can be used.

To avoid thermal bridging and to accommodate extra insulation, the frame can be placed away from the basement wall. A spacing of 40 mm with 38 x 89 mm frame construction will allow a 150 mm batt to fit snugly against the wall. As a rule, the insulation should be about 1 cm wider than the wall cavity so that air passages behind the insulation are eliminated.

Another method of eliminating convective air movement along the wall is to build the stud wall approximately 6 cm away from the wall allowing horizontal installation of insulation batts (RSI 1.4) behind the vertical framing and insulation.

Figure 5.8



Condensation can occur on the cold basement wall. This water will drain to the floor and pool. To avoid water leakage to the living space area a concrete upstand (Figure 5.9) can be cast on the floor. It provides a base for the stud wall and prevents water movement to the interior. Water at the base of the wall will drain below the basement through the wall floor interface. Figure 5.10 indicates a similar detail except that a piece of extruded polystyrene is used in place of the dyke. The foam at the base of the wall also provides some cushion against movement of basement floors in areas of shifting clays.

Figure 5.9

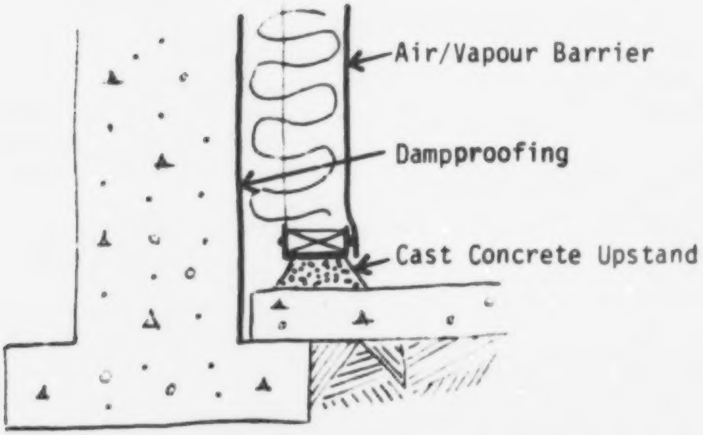
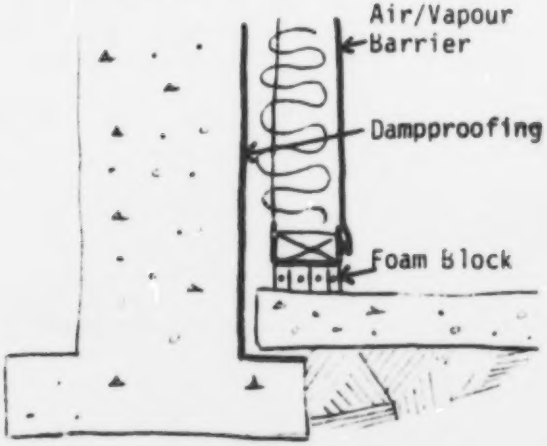

Air/Vapour Barrier
Dampproofing
Cast Concrete Upstand

Figure 5.10


Air/Vapour Barrier
Dampproofing
Foam Block

5.3 Additional Insulation Details

5.3.1 Basement Floors

Many basements have been constructed without a moisture barrier below the basement floor slab. In some cases moisture barriers that have been installed have been damaged during the slab pouring stage to the point where they are ineffective.

Where there is no moisture barrier ground water transfers to the slab. Subsequent evaporation of this water off the surface of the slab contributes to both heat loss and high basement humidity. If a basement is to be finished a moisture barrier should be installed.

Figure 5.11

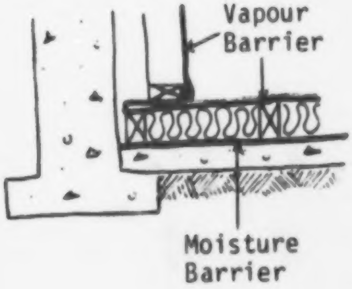
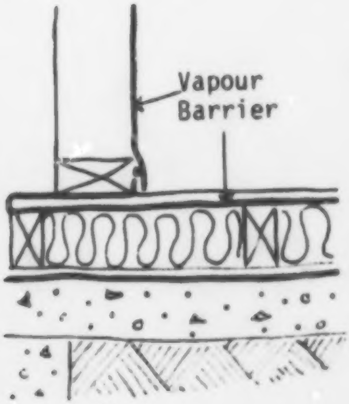


Figure 5.11 shows where a moisture barrier is installed under a frame subfloor. The moisture barrier is placed below the subfloor frame, insulation can then be installed between the framing members. This can be a moisture resistant loose fill insulation such as styrofoam beads or masonry fill vermiculite. Rigid foam or batt insulation may also be used.

Figure 5.12



A vapour barrier should be installed on the warm side of the insulated area and attached to the wall air vapour barrier as shown in Figure 5.12. This type of slab insulation is not recommended in areas of shifting or swelling soils where there is the possibility of uplift of the basement floor.

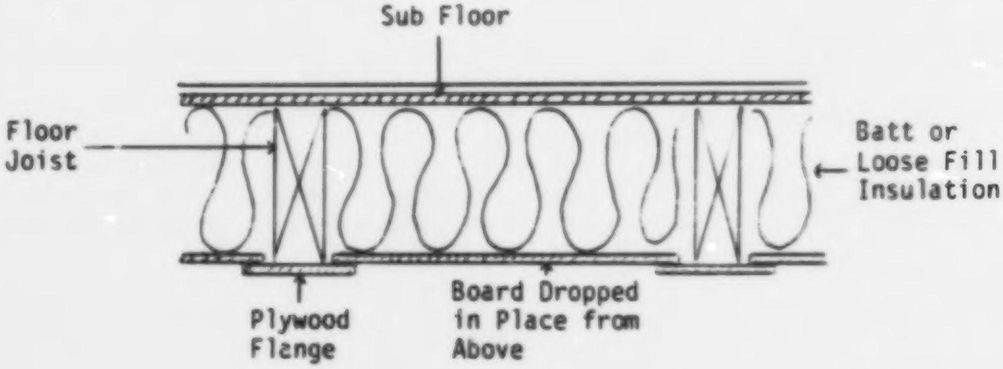
The economic benefit of insulating the basement floor is not yet clear. If a moisture barrier and subfloor must be installed in conjunction with finishing the basement area, insulation may be an incremental cost. The reduction of heat loss from the basement floor area in conjunction with insulation of basement walls may result in penetration of frost below the footings. Heaving or uplift may result.

In areas where shifting clay soils exist, soil swelling and contraction may severely damage a conventional slab basement floor. To avoid this sort of damage a floor platform can be suspended from the foundation walls or upper floor joists (22). A crawl space of 30-60 cm located underneath the suspended floor will provide sufficient area to safely accommodate soil movement. The suspended floor, if desired, can be easily insulated in a number of ways including the approach described for unheated crawl spaces. It should be noted that the crawl space floor may remain in its earthen state but must be covered by a moisture barrier. Section 18F of Residential Standards states that this barrier should consist of a layer of asphalt, concrete and roofing paper of polyethylene (2).

5.3.2 Unheated Crawl Spaces

Since the crawl space is unheated, the main insulation should be provided between the floor joists. Loose fill or batt insulation is most appropriate. Where batt insulation is used it should be supported from below with wire mesh. If loose fill insulation is used, the task of supporting the insulation can be simplified by attaching plywood flanges to the bottom of the joists before installation (Figure 5.13). Thin chipboard can then be dropped in place on top of the flanges. This eliminates the need to work under the joists. The space between the joists should be completely filled with insulation, to make best use of the available space and eliminate any airflow paths.

Figure 5.13


Sub Floor
Floor Joist
Batt or Loose Fill Insulation
Plywood Flange
Board Dropped in Place from Above

Wall vapour barriers should be continued over the subfloor and any penetrations for wiring, plumbing, etc. should be well caulked and sealed. Plumbing runs are best kept to the warmer side of the insulation. Heating ducts and plumbing runs below the insulation should be insulated separately.

Foundations should also be well protected from frost and freezing action. Exterior insulation is considered the best approach as illustrated in Figure 5.14. Footings should be well insulated, particularly if above the frost line, with a rigid insulation skirt. Insulation should extend 60 cm or more from the foundation wall and should provide an RSI-value of 3.0-4.0. Insulation of the foundation helps to increase the effectiveness of the floor insulation and also helps to protect the utilities and appliances in the crawl space against freezing and frost heave.

All crawl spaces must be ventilated by natural or mechanical means to control humidity during the summer months (2).

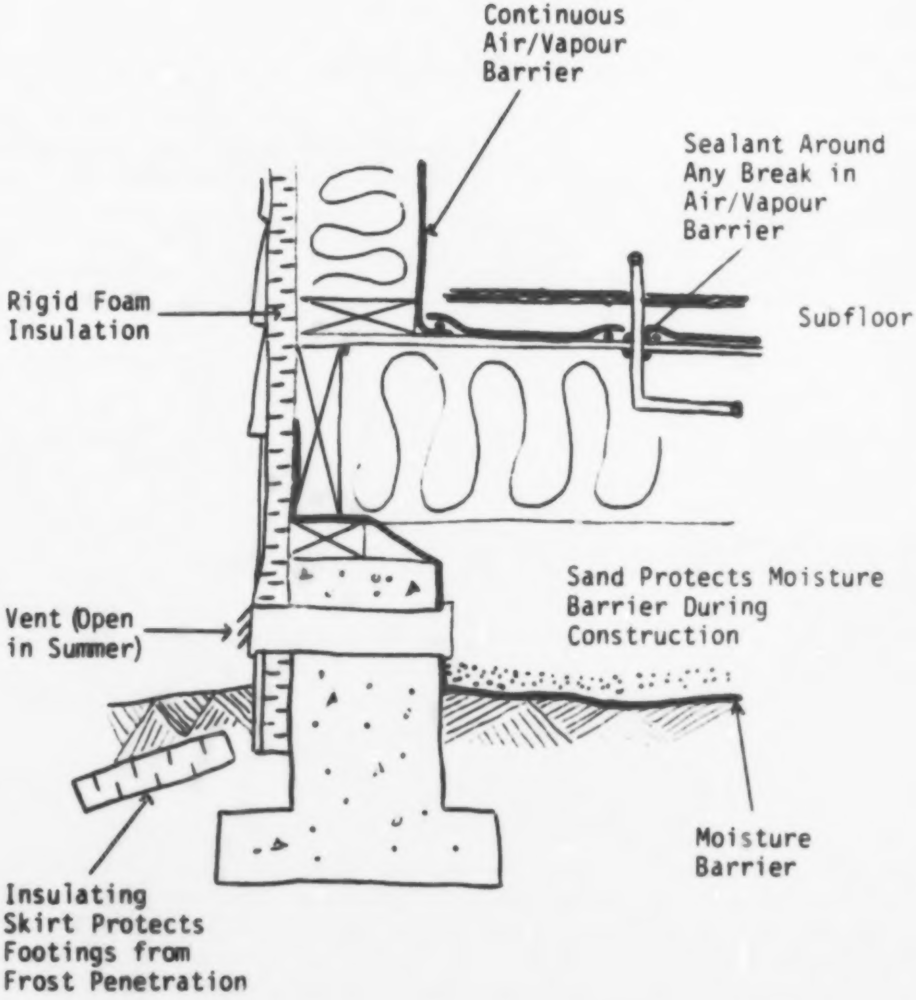
5.3.3 Heated Crawl Spaces

In the past, the crawl space was often used as part of the warm air distribution system. Retrofit action can range from the installation of insulated duct runs from the furnace to interior insulation of the crawl space floor and walls. Insulation of the crawl space or alteration of the heating system may significantly alter the heat loss characteristics of the house at ground level. The installation of exterior and below grade perimeter insulation in conjunction with interior thermal upgrading is highly recommended to protect against frost action.

5.4 Summary

A wide variety of materials, suitable for interior basement insulation, are available. These can be classified as batt or rigid board insulations. Glass fibre batt and mineral wool insulation are usually used in conjunction with a frame wall that can be inexpensively erected by a homeowner. Rigid board can be fastened to the wall utilizing a wood strapping, mechanical fasteners or proprietary fastening systems. A fire resistant material should be installed over all cellular foam products.

Figure 5.14


Continuous Air/Vapour Barrier
Sealant Around Any Break in Air/Vapour Barrier
Rigid Foam Insulation
Subfloor
Sand Protects Moisture Barrier During Construction
Vent (Open in Summer)
Moisture Barrier
Insulating Skirt Protects Footings from Frost Penetration

The advantages of interior applied insulation are as follows:

- Applied on a retrofit basis interior insulation is generally cheaper than exterior insulation and can be easily installed by the homeowner.
- Where strapping or framing of walls is necessary basements can easily be finished. In new construction a finished basement is a marketing feature.

A number of problems may occur as a result of the interior insulation of a basement wall. Thermal upgrading of an existing basement can compound existing problems. Improper treatment of areas such as the header/joist space could initiate structural deterioration. In new housing, it is not clear whether interior insulation will cause long term problems. Structural deterioration usually takes many years to manifest itself and is difficult to access when basement walls and ceilings are finished. On the other hand if insulation and vapour barrier installation details for new housing are adhered to a majority of the problems can be avoided.

The disadvantages to interior insulation of basement walls are as follows:

- In retrofit applications, work may be hindered by existing basement furniture and appliances. Some areas may have to be left uninsulated (e.g., to maintain wall clearance for a furnace). These areas may therefore be subjected to thermal stresses and possible freeze/thaw damage.
- In concrete and masonry walls the insulative effect of the soil may be negated by thermal bridging through exposed above grade surfaces occurring.
- Condensation and moisture build up between the cold wall and insulation may lead to the deterioration of wood products.
- In retrofit situations it is difficult to ensure a continuous and well-sealed vapour barrier due to the interference of plumbing fixtures, wiring and heating ducts. Sealing and insulation of the header/joist area may be particularly difficult and for some types of masonry construction wood rot could result.

- The basement wall, because it is on the cold side of the insulation, may be directly exposed to adfreezing and heave action. Conduction of low above-ground temperatures through the basement wall may also augment frost penetration in the soil adjacent to the wall and lead to footing movement.
- Cast-in-place concrete foundations can be subject to deterioration under repetitive freeze/thaw cycles caused by poor construction practice (e.g., premature backfilling, water addition to premixed concrete). In some cases thermal differential over the height of the wall may be sufficient to induce deterioration.

Section 6

Air Vapour Barriers

Heat loss is made up of two components: losses due to conduction through the fabric of the structure and losses due to natural infiltration and exfiltration. In many houses up to 40 percent of the total heat loss can be attributable to air infiltration, the remaining 60 percent being conduction losses through doors, windows and insulation.

It is essential that air infiltration and exfiltration be reduced as much as possible. In new construction this can be achieved by a continuous air/vapour barrier. In practice the air/vapour barrier is rarely airtight. In older homes it is virtually impossible to achieve an airtight shell, however, much can be done to minimize air leakage.

6.1 Infiltration and Exfiltration

When a house is heated above the ambient outdoor temperature, the air within the house becomes less dense than the outside air, causing it to rise. As the inside air rises and escapes through openings near the top of the house, it is replaced by colder, denser outside air near the base of the house. This is referred to as the stack effect.

When the warm air exfiltrates the structure it carries with it moisture generated within the house. If vapour pressure differences are great enough, moisture can also diffuse through the structure fabric. If there is enough moisture present in the air, moisture losses due to the exfiltration are ten times greater than those due to diffusion. In some leaky houses exfiltration losses may be several hundred times greater than the diffusion losses.

As the warm moisture laden air leaves the house the air cools and the vapour condenses, forming water, ice, and frost in the attic and the top of the walls. The result is water damage and rotting within the upper structure. The effectiveness of the ceiling insulation will also be reduced because of this. Warm air exfiltration and subsequent cold air infiltration also causes heat loss.

To control moisture loss, prevent damage to the structure and minimize heating costs an air/vapour barrier is necessary (1). The air/vapour barrier prevents diffusion of moisture through the structure fabric and prevents air leakage. The air/vapour barrier must provide a continuous airtight seal over the entire inner surface of the structure, of which the basement is only one component.

Heat loss is made up of two components: losses due to conduction through the fabric of the structure and losses due to natural infiltration and exfiltration. In many houses up to 40 percent of the total heat loss can be attributable to air infiltration, the remaining 60 percent being conduction losses through doors, windows and insulation.

It is essential that air infiltration and exfiltration be reduced as much as possible. In new construction this can be achieved by a continuous air/vapour barrier. In practice the air/vapour barrier is rarely airtight. In older homes it is virtually impossible to achieve an airtight shell, however, much can be done to minimize air leakage.

6.1 Infiltration and Exfiltration

When a house is heated above the ambient outdoor temperature, the air within the house becomes less dense than the outside air, causing it to rise. As the inside air rises and escapes through openings near the top of the house, it is replaced by colder, denser outside air near the base of the house. This is referred to as the stack effect.

When the warm air exfiltrates the structure it carries with it moisture generated within the house. If vapour pressure differences are great enough, moisture can also diffuse through the structure fabric. If there is enough moisture present in the air, moisture losses due to the exfiltration are ten times greater than those due to diffusion. In some leaky houses exfiltration losses may be several hundred times greater than the diffusion losses.

As the warm moisture laden air leaves the house the air cools and the vapour condenses, forming water, ice, and frost in the attic and the top of the walls. The result is water damage and rotting within the upper structure. The effectiveness of the ceiling insulation will also be reduced because of this. Warm air exfiltration and subsequent cold air infiltration also causes heat loss.

To control moisture loss, prevent damage to the structure and minimize heating costs an air/vapour barrier is necessary (1). The air/vapour barrier prevents diffusion of moisture through the structure fabric and prevents air leakage. The air/vapour barrier must provide a continuous airtight seal over the entire inner surface of the structure, of which the basement is only one component.

6.2 Installation

The material most widely used as an air/vapour barrier is 0.150 mm polyethylene. Regardless of the material used, it should be installed to provide a completely sealed envelope, except for openings such as doors and windows. All joints between sheets of polyethylene should be made against solid wood backing. Caulking should be placed in a line between the two overlapping sheets; the staples are then driven through the caulking line into the wood member at six inch intervals. At a joint between two large sheets of polyethylene they should overlap at least one stud or truss space (1).

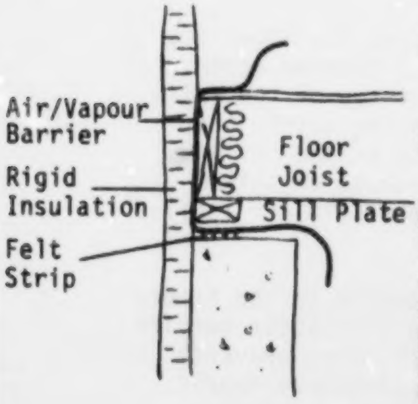
Where the polyethylene is likely to be damaged during construction it should be protected with thin sheets of plywood or panel material. Typical trouble spots are the outside of the header and the loose-strip of polyethylene left at the top of the basement walls to be joined to the wall vapour barrier later.

Before the air/vapour barrier is covered it should be carefully inspected for damage and poor joints. Small holes can be repaired using vapour barrier tape. Large holes can be repaired with a generous piece of polyethylene, caulked to the surrounding sheet at the nearest wood members.

6.3 Installation in the Floor Joist-Header Section

Moist air infiltration occurs in the lower portion of the structure. The most serious leakage area is the floor joist-header section where as much as 60 percent of all air infiltration occurs. The method used for installing an air/vapour barrier depends on the construction of this section.

Figure 6.1

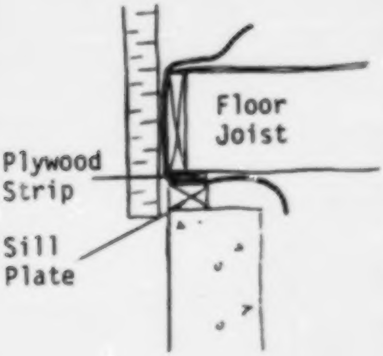


6.3.1 Air/Vapour Barrier Installation During Construction

When the header is mounted on a sill plate which is bolted to the basement wall, installation of the vapour barrier is simple and effective. During construction the vapour barrier is passed under the sill plate around the outside of the header and under the bottom plate of the first floor stud wall as shown in Figure 6.1. To protect the air/vapour barrier from abrasion by the rough concrete, a felt strip can be placed between the air/vapour barrier and the basement wall.

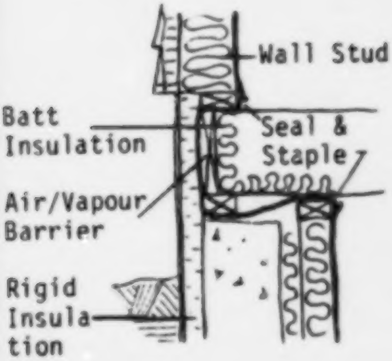
If the insulation is terminated at the top of the foundation wall, the sill plate can experience low temperatures because of heat loss through the concrete. This can cause condensation at the sill plate, so it should be placed outside the air vapour barrier as in Figure 6.2. If the insulation is continuous down the exterior wall the air/vapour barrier can be placed under the sill plate as in Figure 6.3.

Figure 6.2



Rigid foam insulation can be installed on the outside of the header while additional insulation is placed on the inside. Care must be taken to ensure that the air/vapour barrier is placed on the warm side of the dewpoint location. As a rule the insulation on the outside of the air/vapour barrier must have twice as much thermal resistance as that on the inside. The points where the air/vapour barrier meets the stud wall, in both basement and first floor should be caulked to the wall vapour barrier to complete the seal as in Figure 6.3.

Figure 6.3



If a vapour barrier has been installed during construction, the floor joist-header area can be insulated using fibreglass batts or rigid foam materials. Figure 6.3 illustrates this and indicates that a second vapour barrier is not necessary.

The same general technique for installing insulation and air/vapour barrier applies to pressure-treated wood foundations as shown in Figure 6.4.

When the floor joists are embedded in the basement wall concrete, it is not possible to install a continuous air/vapour barrier during construction.

All joints in the header space should be caulked to ensure airtightness. During construction a bead of sealant is placed between the subflooring and the bottom plate of the first floor framing as illustrated in Figure 6.5. The header and joists are caulked where they meet the concrete wall and the subfloor. These steps will reduce air infiltration to a negligible level. But they do not provide a good vapour barrier action. There will probably be some build-up of frost at the header and on top of the concrete foundation, since there is no air circulation to carry away the water vapour. The space should be insulated and sealed with an air/vapour barrier to reduce the risk of structural deterioration.

Figure 6.4

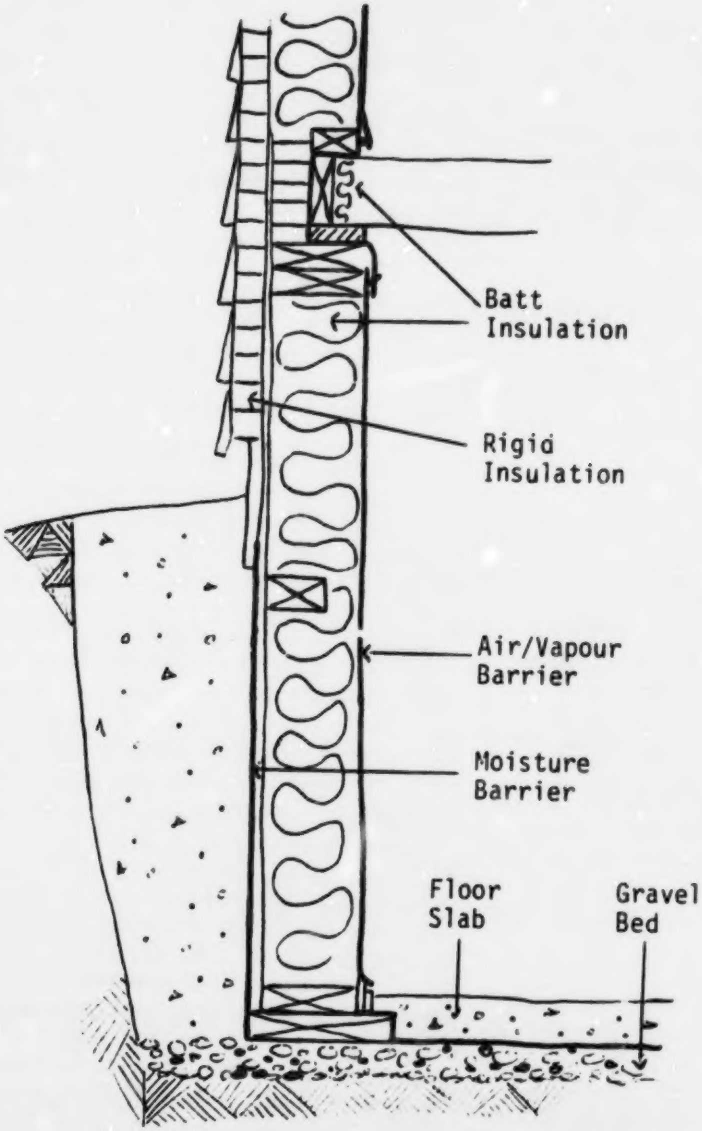
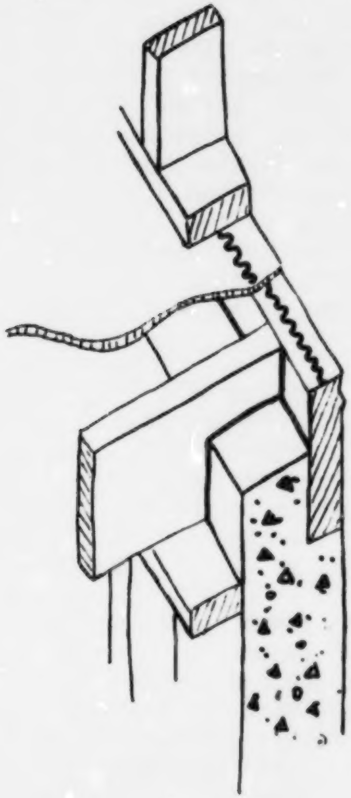
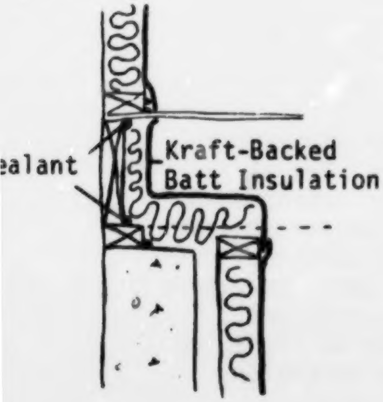

Batt Insulation
Rigid Insulation
Air/Vapour Barrier
Moisture Barrier
Floor Slab
Gravel Bed

Figure 6.5



igure 6.6



6.3.2 Retrofit Air/Vapour Barrier Installation

Retrofit installation of air/vapour in the floor joist-header area involves three steps:

- caulking the area to ensure airtightness;
- filling the space with insulation; and
- sealing the area with an air/vapour barrier.

After sealing the joints against air penetration, the insulation is installed, and the air/vapour barrier is placed over the insulation. This can be done in several ways. For instance:

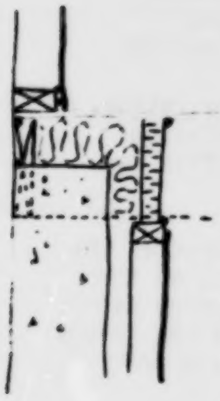
- If kraft-backed batt insulation is used as the insulation the kraft backing will act as the air/vapour barrier, provided the backing is sealed to the subfloor, the sides of the joists and the stud frame wall as illustrated in Figure 6.6.
- Continuity of the vapour barrier can also be achieved between the floor joists by caulking a low permeability, rigid insulation panel to the surrounding members as shown in Figure 6.7.
- A third approach, Figure 6.8, shows how notches in the wall board fit between the floor joists up to the subfloor. A bead of sealant is placed along the top plate of the stud wall and the gypsum board where it meets the joists and subfloor. The gypsum board must be coated with a low-permeability paint.

Any of these methods of sealing the floor joist-header section can be complemented by sealing the space between the subfloor and the joists. A 5 cm headless finishing nail is driven across the joist and the caulking sealant is applied from the air/vapour barrier to the nail.

In both new and retrofit construction, using any joist-header design, the vapour barrier for the framed basement wall is usually a 0.150 mm polyethylene sheet. The sheet is caulked then stapled to the bottom plate of the wall which is in turn caulked to the basement floor. The sheet is brought up to the top plate and stapled into place. The vertical edges are stapled to the studs, and the joints are overlapped 15cm and caulked. The polyethylene sheet is caulked to the air/vapour material used between the joists to ensure a complete seal.

6.3.3 Sealing the Support Beam

Figure 6.7



When attempting to ensure a tight and continuous vapour barrier in both new and retrofit construction, the area around multiple support beams may be difficult. This is especially true when the support beam is cast in place in the basement wall. While the concrete cures it shrinks, leaving space between the wall and the beam allowing air to infiltrate the gaps in the ply of the beam. The air penetration between the ply travels along the interior of the beam bypassing the wall air/vapour barrier. Exposed joints can be sealed with a good caulking material but air infiltration through seams of the beam presents a problem.

A relatively simple approach to sealing the support beam is shown in Figure 6.9. The beam is wrapped in polyethylene, caulked and stapled. The interior vapour barrier can subsequently be affixed to the end of the sleeve. A drawback of this approach is that the polyethylene may be damaged during the construction process.

Figure 6.8

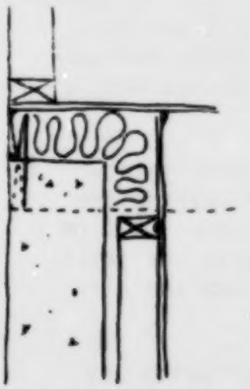


Figure 6.10 details a method of sealing the support beam which is not as susceptible to damage during construction. The plys are caulked at the end of the beam and carried along the beam past the interior wall air/vapour barrier. Support beams in existing structures can be a significant source of air infiltration. Figure 6.11 illustrates how the support beam is sealed in an existing structure. Quarter inch holes are drilled vertically between the ply. Sealant is then applied under pressure to fill these holes. The sealant is then carried along the joints in the beam to the wall air/vapour barrier. The use of caulking between ply rather than polyethylene has been reccommended by the Saskatchewan Research Council.

Figure 6.12 details the placement of the air/vapour barrier where it meets the support beam. The air/vapour barrier which seals the header is lapped down over the interior wall air/vapour barrier and sealed where it meets the support beam. It is continued out over the support beam and sealed. The wall air/vapour barrier is sealed around the support beam as well. Where interior insulation and air/vapour barriers are not installed the vapour barrier should be sealed directly to the wall.

Figure 6.9

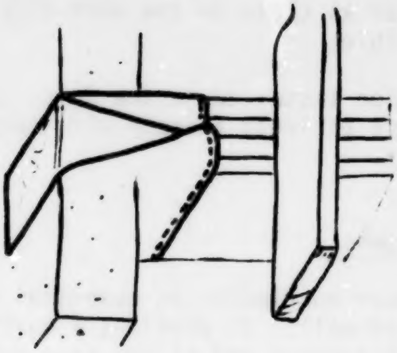


Figure 6.10

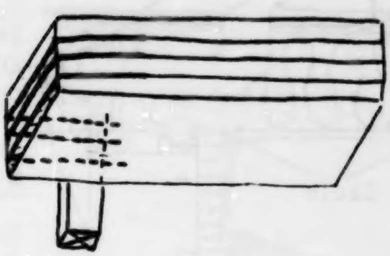


Figure 6.11

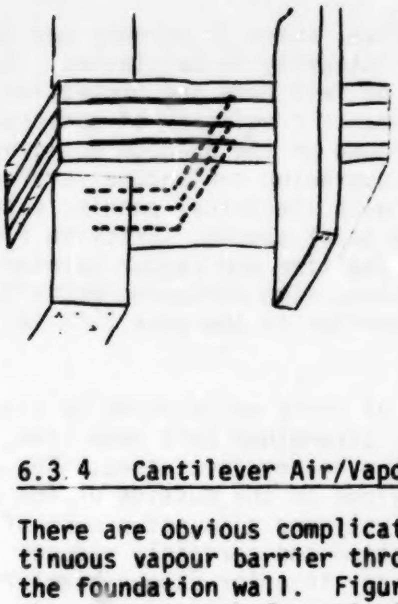
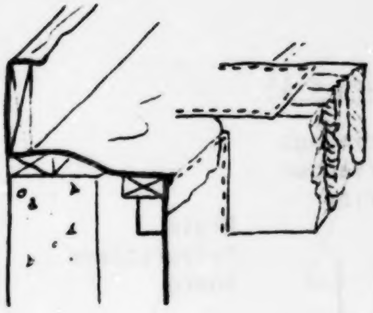


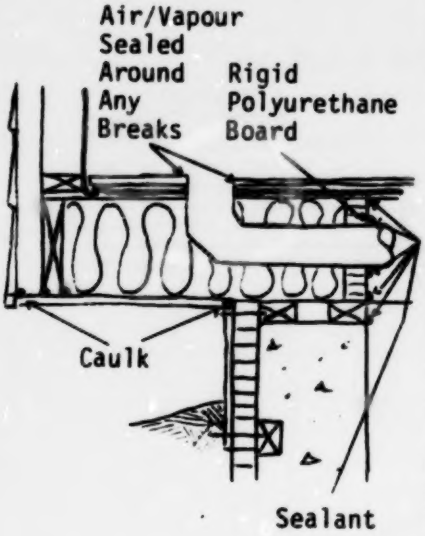
Figure 6.12



6.3.4 Cantilever Air/Vapour Barrier

There are obvious complications to maintaining a continuous vapour barrier through a cantilever deck above the foundation wall. Figure 6.13 and 6.14 respectively show an approach for exterior and interior foundation insulation. Rigid insulation with good vapour barrier qualities (e.g., extruded polystyrene) is precision fitted into the joist space and caulked. A strip of vapour barrier placed on the main floor is caulked just above the fitted insulation assuring as continuous a seal as possible.

Figure 6.13



As shown in Figure 6.13 all heating, wiring and plumbing runs that must travel through the cantilever should be caulked and sealed wherever they perforate the air/vapour barrier. Plumbing runs should be installed as close to the warm side of the insulation as possible.

Insulation installed in the joist space should fill the space entirely thereby eliminating convection currents.

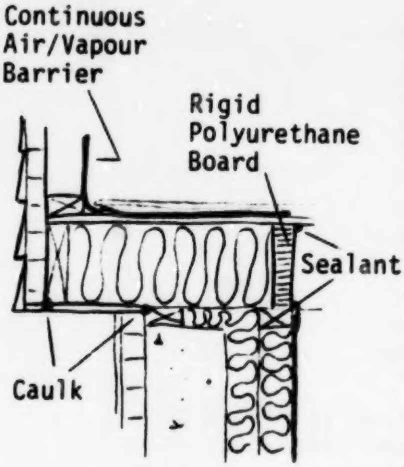
6.4 Summary

The vapour barrier is an essential component of the insulated wall. It provides a barrier against cold air infiltration and at the same time inhibits the movement of water vapour into wall cavities. Heat loss is reduced and possible wood deterioration is prevented.

In practice, there is no easy way to ensure vapour barrier integrity is maintained. During construction, the use of felt pads and protective plywood covers still demands a delicacy of construction techniques seldom found on the average building site. Interior thermal upgrading can become very complicated when dealing with electrical panels, exterior wall heating runs and joist spaces. Friction fitting rigid insulation, caulking and vapour barrier installation are all tedious, time consuming activities. In all, the vapour barrier is the weak link in the insulation process.

The use of rigid polystyrene to the exterior of the wall may strengthen this weak link, particularly around the header/joist area. The application of polyethylene to the outside of the header combined with polystyrene eliminates much of the concern over condensation and certainly reduces infiltration as well as any interior vapour barrier treatment.

Figure 6.14



Section 7

Review and Areas for Further Study

7.1 Economics

7.1.1 Basement Heat Loss

To what degree is it worthwhile to insulate a basement? Much research is being conducted in Canada and other parts of the world to answer this question. The below grade environment around the basement possesses a climate considerably more complex than that surrounding above-grade living space.

For simple two dimensional heat flow between the soil and the basement, winter heat losses decrease in magnitude as depth increases. Table 7.1 illustrates the degree to which depth affects heat loss (6).

Table 7.1 Proportion of Heat Losses for a Basement 1.8 m Below Grade

Depth Below Grade (m)	Proportion of Heat Loss (%)
0.0 - 0.3	38.0
0.3 - 0.6	20.5
0.6 - 0.9	14.3
0.9 - 1.2	11.0
1.2 - 1.5	8.9
1.5 - 1.6	7.3

Source: Boileau, G.G.; Latta, J.K.; "Calculation of Basement Heat Losses", Tec. paper 292, Division of Building Research, National Research Council, 1968.

The formula used to derive the table is based on simple assumptions of heat flow resistance provided by varying depths of soil. In developing the formula, the NRC noted that values for the thermal conductivity of soil range from 0.52 to 2.24 $W/m^2/^oC$, depending on factors such as soil type, density and moisture content. Because soil types and moisture levels are not typical, a cross-the-country process of estimating optimal insulation levels is very difficult.

Calculating basement heat losses is also complicated by other factors, such as the type of floor covering, air circulation patterns in the basement, and the inadequacy of conventional heat loss calculation methods. Monitoring of 14 low energy houses in Saskatoon has indicated that actual heat losses from the basement floors may be 2 to 3 times greater than traditional calculation methods would indicate (4). Initial research indicates that a major heat loss path may be from the basement floor downward to the water table.

Methods of calculating heat loss are being refined by agencies such as the NRC, universities and research institutions and these improved methods are being tested and compared with monitored results (5,14,15, 35,36,40,42,43,47,54). Improvements are incorporating new information on soil thermodynamics and the mechanisms of heat loss from basement and underground structures. While the methods will refine the process of predicting the cost effectiveness of various insulation techniques, the actual thermal performance still appears to depend on site-specific soil conditions that are not fully understood.

Cost of Exterior Insulation - Fundamental in determining the economics of various insulating approaches is the cost of purchase and application of insulation. Much of the application related research concerning basement insulation has been conducted by the Technical Research Council (TRC) of the Housing and Urban Development Association of Canada (HUDAC). The Subcommittee on Foundations and Drainage of the TRC has been involved in an ongoing, multi-phase research program designed to generate guidelines for builders about acceptable and practical ways of designing and installing basement insulation. Among other things, they have done preliminary evaluations of the cost of installing exterior insulation (25). Their results are presented in Table 7.2.

The findings presented in this table are by no means definitive. Insulation of a basement from the interior or exterior is still a relatively new process that will become further simplified as builder skills and insulating products improve.

Cost Effectiveness of Various Insulating Techniques - The most recent work on the cost effectiveness of various insulating techniques has been conducted by John Timusk of the Mechanical Engineering Department of the University of Toronto, for the Ontario Ministry of Municipal Affairs and Housing. The installation costs, performance and payback periods of various insulation options were evaluated (48). Tables 7.3 through 7.5 summarize a portion of his results.

Table 7.2 Estimated Cost Per Linear Metre of Exterior Insulation

		Material Cost Job Site	Labour Cost
		($/Lm)	($/Lm)
1.	Insulation - Type IV or Fibreglass Insulation, RSI 1.4	16.80	1.97
	Metal slots applied to forms	0.03	0.49
2.	Mortar bed for flashing	0.16	1.64
	Parged surface, 300 mm deep Fibre reinforced, parged A or B	2.30	1.31
	Flashing	3.61	1.64
	Tools and Supplies	0.20	-
	Tax 7% on $6.60	0.46	-
		$23.86	$7.05

Total direct cost: $30.91/linear metre

Assumptions

1. A 64 mm thick layer of insulation is applied the height of basement wall (2.28 m)
2. A number of units are insulated at the same time
3. Average house perimeter is 30 m
4. Homes have six windows and several corners
5. Labour base wage = $10.00/hr; burdens are 25% for $12.50/hr cost
6. Tax of 7% is applied to all materials except insulation
7. Job done in 2 stages - installation/flashing and parging after backfill
8. Prices as of January, 1981

SOURCE: HUDAC, "External Insulation of Basement Walls Phase II Report", September, 1981.

Table 7.3 Payback Periods for Heated Basement Internal Insulation Full Height

	Cost per Metre of Basement Perimeter	Degree Days			
		4000°C		6000°C	
		Gas	Elect.	Gas	Elect.
	($)	(years)			
RSI .88 70% Reduction in Heat Loss					
Glass Fibre	30.58	5.3	3.7	2.9	2.0
Type I	28.13	4.9	3.4	2.7	1.8
RSI 1.4 76% Reduction in Heat Loss					
Glass Fibre	35.06	5.6	3.9	3.0	2.1
Type I	31.91	5.1	3.5	2.8	1.9
Insulock	39.59	6.3	4.4	3.4	2.4
RSI 2.1 81% Reduction in Heat Loss					
Glass Fibre	36.21	5.4	3.8	3.0	2.1
Type I	37.01	5.6	3.9	3.0	2.1
Insulock	48.71	7.3	5.1	4.0	2.8

Note: Assumed energy prices are \$3.98/1000 cf for natural gas and 3.25¢/kWh for electricity. The wall is assumed to stand 2.4 metres high.

Table 7.4 Payback Periods for Heated Basement Internal Insulation Partial Height

	Cost per Metre of Basement Perimeter	Degree Days			
		4000°C		6000°C	
		Gas	Elect.	Gas	Elect.
	($)	(years)			
RSI .88 54% Reduction in Heat Loss					
Glass Fibre	16.27	3.6	2.5	2.0	1.4
Type I	14.59	3.3	2.3	1.8	1.2
RSI 1.4 58% Reduction in Heat Loss					
Glass Fibre	18.89	3.8	2.7	2.1	1.5
Type I	16.49	3.4	2.3	1.8	1.3
Insulock	19.82	4.0	2.8	2.2	1.5
RSI 2.1 63% Reduction in Heat Loss					
Glass Fibre	19.63	3.8	2.6	2.1	1.4
Type I	19.04	3.7	2.6	2.0	1.4
Insulock	24.38	4.7	3.3	2.6	1.8

Note: Assumed energy prices are \$3.98/1000 cf for natural gas and 3.25¢/kWh for electricity. The wall is assumed to stand 2.4 metres high.

Table 7.5 Payback Periods for Heated Basement External Insulation

	Cost per Metre of Basement Perimeter	Degree Days			
		4000°C		6000°C	
		Gas	Elect.	Gas	Elect.
	($)	(years)			
RSI 1.4 Partial Height 58% Reduction in Heat Loss					
Type IV	29.58	6.0	4.2	3.3	2.3
RSI 2.1 Partial Height 63% Reduction in Heat Loss					
Type IV	34.04	6.6	4.6	3.6	2.5
RSI 1.4 Full Height 76% Reduction in Heat Loss					
Type IV or Rigid Glass	39.37	6.2	4.3	3.4	2.4
RSI 2.1 Full Height 81% Reduction in Heat Loss					
Type IV or Rigid Glass	48.29	7.2	5.0	4.0	2.8

Note: Assumed energy prices are $3.98/1000 cf for natural gas and 3.25¢/kWh for electricity. The wall is assumed to stand 2.4 metres high. Costs do not include excavation of basement wall.

Included in his evaluation was fibreglass batt insulation, rigid fibreboard insulation, polystyrene Type I and IV as well as a proprietary insulation and fastening system called Insulock. Calculations are made for 4000 and 6000°C degree day climates. Heat loss figures and costing figures were based upon methods developed by Scanada Consultants of Ottawa.

7.2 Insulation Associated Problems

A major focus of this study has been to identify structural and thermal problems that may result from certain insulation approaches. The following two sections examine the problems that may occur in conjunction with internal and external insulation application.

7.2.1 Exterior Insulation

Adfreezing - Rigid insulation at grade level may be subject to adfreezing and heave action. Freezing of soil to the insulation and subsequent ice lensing in the frozen soil will cause upward pressure on the insulation. Results of adfreezing may be:

- breakage of insulation
- damage to protective coating and flashing detail
- uplift of insulation

Adfreezing damage may be prevented by the installation of a double layer of polyethylene between the soil and the insulation/protective covering. The double sheet will act as a slip coat allowing the soil to heave upward but preventing a solid bond. However, experience with adfreezing on exterior insulation is limited and it is difficult to estimate the extent to which it will be a problem. Likewise, the long-term success of polyethylene slip coat to prevent adfreeze damage has not been confirmed.

Shifting Soils - Expansion and contraction action of expansive clay soils on exterior insulation can result in damage to the insulation and loss in thermal efficiency. Freezing of clay soil to the insulation may pull insulation away from the wall, depending on how insulation is attached and specific soil conditions. A double polyethylene slip coat may be effective against the movement of clay soils.

Ideally, when insulation is installed a less expansive backfill with good drainage characteristics should be used. Some soil movement may take place due to settling, and therefore insulation should be positively affixed to the wall.

Frost Heave of Footings - A well insulated basement may be so effective at preventing heat loss that under certain conditions the frost line may move below the foundation footing. In such an instance, freezing and ice lensing could occur below the foundation footing resulting in an upward heave. Serious damage to footings and walls may result.

Once the soil beneath the footings has gone through a freeze/thaw cycle it may no longer provide a stable base for the footings. Further footing displacement may result. However, only under extreme conditions (e.g., wet fall, quick winter freeze, low and sustained winter temperatures, little or no snow cover, all combined) is it likely that frost penetration to footings of a heated basement will result. Shallow crawl space foundations may be more vulnerable. Several methods of preventing frost penetration below the footing have been advocated including:

- A sloped skirt of insulation placed around the perimeter of the foundation above the footing level. An insulating skirt, used in combination with partial vertical insulation, avoids the extra cost and effort of excavation and insulation to the footing level. The effectiveness of this approach is not clear. Further investigation is needed to determine the cost effectiveness of utilizing a horizontal skirt of insulation around the perimeter of a building foundation.
- Installation of the near horizontal skirt above the footing. This can also prevent freezing and possible damage of the drainage and tile systems.

7.2.2 Interior Insulation

Adfreezing - Under the right conditions, adfreeze action can occur directly to the foundation wall of interior insulated basements. Cracking and heaving of walls can result.

Walls of block or brick construction are likely to be most vulnerable to adfreezing action. Lateral mortar joints lack the tensile strength to resist vertical heave action. The effect of adfreezing on a solid poured concrete wall depends on the strength of the wall and severity of the adfreeze action. In extreme cases, walls may be lifted completely off footings. Methods for avoiding adfreezing damage include:

- The installation of a double layer polyethylene slip coat between the wall and soil. The polyethylene prevents the formation of a soil-wall bond and allows for vertical movement of the soil.

- Exterior waterproofing, layered and of a bituminous nature. Any bond that might be formed between the soil and bitumen material shears upon heave movement. However, the subsequent damage to the coating may result in water leakage into the basement.

Thermal Stress - Masonry, stone and cement foundation walls insulated from the interior and deprived of heat gain from the house, may be subject to cracking due to both temperature variations and freeze/thaw cycling on the wall. Whether cracking occurs or not depends on specific flaws and weaknesses in the foundation material itself. These flaws and weaknesses are generally a product of poor or improper workmanship when the wall was under construction. In basements with poured concrete walls these flaws can result from:

- adding extra water to the cement mixture to allow for better movement of cement around forms
- pouring cement from a height that will cause separation and settlement of aggregate in the lower portion of the wall
- removing wood forms or backfilling before cement is properly cured.

Poorly or partially insulated basements may be more prone to cracking than fully insulated or uninsulated basements. For example, insulation installed to two feet below grade, as recommended in the National Building Code, subjects the basement wall to a warming action from the basement and a cooling action from the exterior exposed face of the wall (1). During the winter, depending on outside conditions, freeze/thaw action could cycle throughout the top half of the wall. Flaws in the wall may be further weakened and cracking may result.

There is little indication how widespread cracking problems may be. However, discussions with officials of the Ontario Home Warranty program seem to indicate that over the past few years, as interior insulation has increasingly been used, reports of basement cracking have grown in frequency. In one two-day period during the month of March 1981, it was estimated that 300 reports of cracking were received. While a direct correlation between foundation flaws, poor construction technique and thermal stress is difficult to make at this time, the subject obviously needs more research.

If cracking of basement walls due to thermal stress is suspected, exterior insulation should be applied to the wall. In some cases, external insulation of the exposed above grade portion of the wall may be sufficient to alleviate temperature differentials and thermal stress in the wall.

It is highly unlikely that building practices that lead to weakening of the wall can be prevented in the residential housing industry. Weaknesses caused by watered down concrete or improper backfilling are difficult to identify unless the actual weakening action is observed. After the fact, the cause of a visible flaw is difficult to relate to a specific action.

Frost Heave - If a basement wall is fully insulated from the inside or outside, the frost line may penetrate below the foundation, due to the lack of heat loss to the surrounding soil. Frost action below the footing can result in:

- upward heave of footings
- loss of stability of soil underneath footings
- damage to the footing drain system due to freezing.

Insulation of basement floors will further reduce heat loss to the soil and increase the possibility of frost heave.

Interior insulated basements may be more susceptible to frost penetration to the footings than exterior insulated walls. Thermal bridging from the above grade portion of the wall could contribute to soil cooling and frost penetration.

Frost penetration to the footings and drain system can be prevented by the installation of a near horizontal insulating skirt around the perimeter of the basement wall, above the footings. Only under extreme conditions (e.g., wet fall, quick winter freeze, low and sustained winter temperatures, little or no snow cover; all combined) is it likely that frost penetration to footings of an insulated basement will result. Shallow crawl space footings and walks may be more vulnerable to frost action, and should be insulated from the exterior with a horizontal insulated skirt.

Moisture, Condensation and Wood Deterioration - There are several ways that high humidity or condensation in an interior insulated basement may lead to wood deterioration. Relative humidities greater than 80 percent are generally conducive to wood rot. Conditions that lead to wood deterioration include:

- Interior insulation. Interior insulation necessarily reduces the area over which moisture can evaporate from the wall and therefore the relative moisture content of the wall may increase. This moisture is usually absorbed up through the footings. Wood materials directly in contact with the wall (e.g. floor joists) may be subject to condensation and high humidity. Occurrence of this type of deterioration depends on the condition of exterior dampproofing and drainage, soil moisture content and capillary characteristics of the wall. Condensation and subsequent wood deterioration is unlikely occur in new construction. Retrofit action around the header/joist area in masonry or cement walls where wood is embedded into the wall should be taken with care and periodically monitored. One authority suggested that insulation of the header/joist area of masonry buildings be avoided until more is known of the possible consequences (48).

- Poor vapour barrier installation in conjunction with interior insulation. This may result in condensation occurring on cold surfaces such as the basement wall. Wood products in contact or proximity to these cold surfaces may experience conditions conducive to rotting. All interior insulated walls are likely to experience some frosting and condensation. Water may collect at the wall base.

Wood deterioration can be avoided through:

- the use of pressure treated wood products in suspect areas
- dampproofing of interior walls to grade level with polyethylene, or bitumen based material
- mechanical dehumidification of the basement areas

Partial exterior insulation over the header area and slightly below grade will eliminate the need to insulate the interior joist space and eliminate the possibility of condensation.

7.3 Areas for Further Study

7.3.1 Review of Building Codes and Standards

Both local and national building codes, standards and guidelines related to basement construction and insulation need to be reviewed to ensure that they are applicable to new insulation and construction techniques. Two issues that require further investigation are the use of moisture barriers below poured slab floors (causes uneven curing) and the insulation and sealing of basement walls before they are properly cured.

Existing standards and practices also have to be reaffirmed in the industry. For example, the practice of watering down concrete as it is poured into forms appears to be widespread in the construction industry. Other practices such as removing forms and backfilling concrete foundations before they have had time to properly cure are reported to be common in the housing industry.

7.3.2 Internal Insulation of Basements

The structural implications of internal insulation of residential basements is still not clear. Many concerns are based on theory, speculation and sporadic reporting. This is not to say that these concerns are frivolous. Structural deterioration usually occurs over an extended period of time in areas that are difficult to inspect. Seemingly minor problems of mould and mildew, and cracking and spalling of basement walls may not have an immediate effect on the homeowner but could have an effect on the useful lifetime of the home.

Inspection, documentation and monitoring the occurrence and non-occurrence of structural problems associated with internal insulation of residential basements should be carried out to ensure that techniques being used do not threaten residential structures. In some cases, information is already being collected by provincial home warranty programs. The specific cause of problems should be identified whenever possible. Do problems occur as a result of insulation or as a result of a particular application? Should exterior insulation be used in all cases? Given the likelihood that thermal upgrading activity will increase and insulation of new housing will continue it is important that potential structural problems be identified well before they occur.

7.3.3 Workmanship and Building Practice

Many basement problems are directly related to poor workmanship or improper building practice. In some cases energy conservation measures will aggravate an existing flaw. There is a need to identify the causes of these flaws and to specify the building practices that will prevent them. The most effective approach to incorporating energy conservation measures can often involve the adoption of new building techniques. There is a need to identify products and construction approaches that simplify the building process and at the same time ensure that the quality of the work is acceptable.

7.3.4 The No-Basement Alternative

The residential basement has evolved from the need to provide a stable foundation for the structure. It has come to be viewed as an integral part of the habitable area of the house. In light of the construction costs and the difficulties of properly insulating the basement without raising the risk of structural damage, the no-basement alternative warrants serious study.

Costs for constructing a basement and for constructing an equal quantity of space above ground on a grade beam-pile foundation are comparable (19). Even though the basement does not require exterior cladding, it must be excavated, and the walls constructed of concrete or masonry. These walls are more costly than wood frame walls.

The quality of the interior space is also a factor; the windows in a basement are generally not as aesthetically pleasing as those in above grade spaces. Unless insulated or carpeted, basement floors are uncomfortable to the touch due to conduction.

In areas where structural problems are not likely, such as in sandy soils, the construction of a basement can be considered as comparable to that of above ground construction. Where structural problems occur frequently, such as in prairie clay soils, there is justification for replacing the basement with an above-ground structure.

7.3.5 Gas Infiltration

Basements may be susceptible to infiltration of radon and methane gas. In sufficient quantities, these gases pose serious health hazards. This is a particular concern to well-insulated, airtight homes. A perimeter drain system leading to a central basement drain aggravates the problem of gas infiltration. The drain system permits the gas to enter the basement more easily and in larger volumes.

The magnitude of radon and methane gas infiltration needs to be documented. The areas in or conditions under which it is likely to be a serious problem need to be documented and the best means of minimizing the problem need to be specified.

Annotated Bibliography

Title	National Building Code of Canada 1980.
Author(s)	Associate Committee on the National Building Code
Publisher/Date	National Research Council Canada
Available from	National Research Council Canada Montreal Road Ottawa, Ontario
Catalogue and Indexing Numbers	NRCC 17303
Key Words	
Sector Applicability	Residential Basements

Abstract	The National Building Code is a set of minimum regulations respecting the safety of Buildings with reference to public health, fire protection and structural sufficiency. The code is designed to be adopted in whole or part for legal use by any provincial or municipal authority in Canada.

Title	Residential Standards 1980.
Author(s)	Associate Committee on the National Building Code
Publisher/Date	National Research Council of Canada
Available from	National Research Council of Canada Montreal Road Ottawa, Canada
Catalogue and Indexing Numbers	NRCC No. 17304
Key Words	
Sector Applicability	Residential Basements

Abstract

This document presents guidelines produced for Canada Mortgage and Housing Corporation and is based on the requirements outlined in Part 9 of the National Building Code for buildings for residential occupancy. In some cases the guidelines go beyond the scope of the National Building Code.

Residential Standards 1980 is meant only to apply to residential buildings up to 3 stories in height and not exceeding 600 m^2 in area.

Areas covered that are pertinent to basement design and construction include: Section 12, Excavation; Section 13, Waterproofing and Dampproofing; Section 14, Drainage; Section 16, Slabs on Ground.

Title	Preliminary Computed Space Heating Performance Results for Fourteen Low Energy Passive Solar Houses in Saskatoon, Saskatchewan.
Author(s)	Besant, R.W.; Bengtson, S.
Publisher/Date	Department of Mechanical Engineering, University of Saskatchewan, August, 1981
Available from	University of Saskatchewan Department of Mechanical Engineering Saskatoon, Saskatchewan
Catalogue and Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This study investigates fourteen commercially built low energy passive solar houses with respect to design heat losses and auxiliary space heating load. A steady state lumped component computer model is used to predict the heat losses and gains from each component. Long term monthly average values are used for all the environmental parameters and constant properties are used for each house's components. The analysis indicates that standard design methods for air infiltration, attic insulation and uninsulated basement floors under-predict auxiliary energy use by an average factor of two. A modified method of calculating heat losses for these components leads to more accurate average values of auxiliary energy, although the standard deviation of the discrepancy on each house was 17 percent of the total heat loss. The significance of these aspects is discussed.

This paper is an interim report of ongoing research being conducted on 14 homes constructed for the HUDAC parade of homes in Saskatoon. This paper is of interest primarily to those involved in the modeling or monitoring of below grade thermodynamics.

Title	A Preliminary Report on the Uninsulated Basement Floor Heat Loss in 14 Low Energy Houses in Saskatoon, Saskatchewan
Author(s)	Besant, R.W.; Hamlin, T.
Publisher/Date	Department of Mechanical Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, July, 1981
Available from	University of Saskatchewan Department of Mechanical Engineering Saskatoon, Saskatchewan
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This report examined fourteen low energy house basements for the net heat transfer rates to the basement floors by radiation and convection heat transfer during the late spring of 1981. A new method of analysis is used to determine these heat losses utilizing temperature data on the surfaces of basement floors, walls and ceilings as well as air temperature and air circulation rates. Initial results suggest that basement floor heat losses in low energy houses may be 2 to 3 times greater than traditional methods of calculation would suggest.

This paper presents the results of testing on the energy efficient homes built in 1980 for the HUDAC Parade of homes in Saskatoon. Its focus is on temperature and heat loss measurement of below grade space. It is very likely that this research will provide the foundation for further development of thermodynamic models for prediction of below grade heat losses.

Title	Energy Comparisons and Where to Insulate Earth Sheltered Buildings and Basements
Author(s)	Blight, T.
Publisher/Date	Energy, Vol. 5, pp. 451-465, Pergamon Press, 1980.
Available from	
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract	This paper takes a general approach in discussing various insulation techniques for earth sheltered buildings and basements for conventional housing. It reviewed the low energy features of underground housing, as well as design principles relating to thermal mass, passive solar gain and use of landscaping and vegetation to minimize energy use. A computer simulation is presented comparing an earth-sheltered home to conventionally constructed single and two storey homes. The advantages of horizontal and vertical insulation for basements and underground houses are presented. Overall, this paper provides a positive review of underground housing techniques and relates many of the design problems encountered to the design and insulation of conventional basements.

Title	Calculation of Basement Heat Losses
Author(s)	Boileau, G.G.; Latta, J.K.
Publisher/Date	National Research Council, Division of Building Research, December 1968
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Technical Paper No. 292
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper presents a simple hand calculation technique for estimating basement heat losses. This method assumes steady state heat flow along semi-circular paths centered on the intersection of the ground surface and the basement wall. It allows for heat loss from walls and other materials by converting them to relative thicknesses of soil. This procedure was adapted by the American Society of Heating, Air Conditioning and Refrigeration Engineers (ASHRAE) and has been included in the ASHRAE Fundamentals Handbook.

In light of current research utilizing computer modelling techniques, the approach outlined in this paper is somewhat dated. This research indicates that the thermal interactions between basement and outside soil are considerably more complicated than described in this model. The model only allows for seasonal prediction of heat losses.

Title	Mark XI Energy Research Project, Comparison of Standard and Upgraded Houses.
Author(s)	Brown, W.C.
Publisher/Date	Division of Building Research, National-Research Council of Canada, June 1980.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Building Research Note No. 160
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper presents some of the energy consumption data obtained from four houses of similar floor plan, and orientation, with various heating systems and insulation levels. The objectives of the study are to demonstrate the energy savings which result from upgrading the thermal resistance and air tightness of the building envelope, determine the accuracy of mathematical models in predicting energy consumption, and determine the effect of occupancy on energy usage. The analysis of the data collected during the first complete heating season of the project indicates that the increased insulation and air tightness of the upgraded house has reduced the annual heating load by 31 percent from the standard insulated house. Only 10 percent of this reduction in heating load occurs because of the increased insulation levels on the basement of the upgraded house. Moreover, a significant portion (25 percent) of the heat loss from the houses occurs below grade. A comparison of the measured heating loads with three heating load prediction methods indicates reasonable agreement between the Net Annual Heat Loss Factor Method (NAHLF) and ASHRAE Modified Degree-Day Method (MDD) prediction methods and measured loads.

Title	Construction Guide for Preserved Wood Foundations, Revised edition with Supplements No. 1 and 2.
Author(s)	Canadian Wood Council
Publisher/Date	Canadian Wood Council
Available from	Canadian Wood Council 85 Albert Street, Ottawa
Catalogue & Index Numbers	PWF-1
Key Words	
Sector Applicable	Residential Basements

Abstract

This publication provides practical design and construction information for preserved wood foundations, and can be used as a guide to acceptable building practice. Construction features of various types of foundation designs have been outlined. A detailed discussion of the various components of preserved wood foundations includes: preservative treatment, excavation and site preparation, both wood and concrete footings, and details of wall and floor construction. In Canada, Central Mortgage and Housing Corporation accepts wood foundations for houses built with National Housing Act financing, provided they are built in accordance with this guide.

Title	Moisture and Thermal Considerations in Basement Walls
Author(s)	Crocker, C.R.
Publisher/Date	National Research Council, Division of Building Research, 1974
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Canadian Building Digest No. 161
Key Words	
Sector Applicability	Residential Basements

Abstract	This study examines measures that can be utilized to control moisture in solid masonry and concrete block walls. It also details a method for exterior insulation of basements.

Title	House Basements
Author(s)	Crocker, C.R.
Publisher/Date	National Research Council, Division of Building Research, January 1961, amended 1974
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Canadian Building Digest No. 13
Key Words	
Sector Applicability	Residential Basements

Abstract	A basic review of the techniques used during construction to ensure a dry basement and the proper procedure for applying an interior finish to walls and floors. This publication is written only as a general guide and is dated and limited in its scope as it only discusses solid concrete walls.

Title	Laboratory and Field Investigation of Moisture Absorption and its Effect on Thermal Performance of Various Insulations
Author(s)	Dechow, F.J; Epstein, K.A.
Publisher/Date	American Society for Testing and Materials, 1981
Available from	American Society for Testing and Materials 1916 Race Street Philadelphia, Pa. 19103
Catalogue & Indexing Numbers	ASTM STP 660
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper reports on the moisture performance characteristics of various thermal insulations under both laboratory and field conditions. Moisture effects such as freeze thaw cycling in the presence of water, water absorption and water vapour transmission which occur in insulation in upside down roof systems and below grade applications, reduced the thermal efficiency of all insulations tested. Minimum performance criteria for insulation are discussed. The insulations tested include glass fibre, fibre board, expanded bead polystyrenes, extruded polystyrene, polyurethanes and cellular glass.

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Title	Glass Fibre as a Draining Insulation System for the Exterior of Basement Walls. Presented at the DOE-ORNL/ASTM Conference, December 8-11, 1981 by J.M. Dewil
Author(s)	Decon, Philip C. Fibreglass Canada Inc., Sarnia, Ontario
Publisher/Date	
Available from	Fibreglass Canada Inc. P.O. Box 3005 Sarnia, Ontario N7T 7M6
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper examines the complex heat loss patterns from residential basements and investigates measures of reducing heat loss. In this study a section of basement wall and floor and the surrounding soil was modelled and used in a two dimensional finite element heat transfer analysis. Various configurations of insulation (partial and full wall, interior and exterior) were used during the analyses under steady-state conditions. A transient analysis of a one-year period was performed on a similar section that modelled an actual test basement. The measured data was in good agreement with the predicted values.

The specific focus for this study was the use of fibrous insulation (compacted glass fibre) as an insulating and drainage layer applied externally to basement walls. General guidelines are provided for installation and the results of monitoring a below grade installation are presented. This paper chronicles the North American product development and testing of a product widely used in Sweden for the past 10 years. This product has recently been introduced to the Canadian market.

Title	Dofasco Steel Basement Systems Manual February 8, 1982 Issue
Author(s)	Dofasco Inc.
Publisher/Date	
Available from	Dofasco Inc. Hamilton, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract	This document can be considered a reference manual for the design and construction of steel basements as developed by Dofasco. Stress factors and design loadings are discussed with extensive references made to the National Building Code 1980 and Residential Standards 1980. Specific features of a steel basement are reviewed and discussed. The sequence of construction for a steel basement is presented along with photographs and diagrams of the assembly process.

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Title	Energy Exchange Between Earth Sheltered Structures and the Surrounding Ground
Author(s)	Eckert, E.R.G.; Blight, T.P.; Pfender, E.
Publisher/Date	Energy, Vol. 4, pp. 171-181, Pergamon Press, 1979. Also, Earth Covered Buildings: Technical Notes, 1980, pp. 226-250.
Available from	
Catalogue & Indexing Numbers	NTIS Pub # CONF-7805138-P1
Key Words	
Sector Applicability	Residential Basements

Abstract

Experimental results from the measurement program at Williamson Hall, a large earth sheltered building at the University of Minnesota, are presented. The temperature field and the moisture field of the soil surrounding the building are presented for each month as are the heat fluxes at various points on the walls. Results of thermal conductivities of soil samples at various densities and moisture contents are given. A novel, unsteady method for thermal conductivity measurement is introduced. Results of a computer simulation of the temperature field are also presented. The experimental methods, instrumentation and layout are discussed.

The experimentation carried out in this project is unique in that it attempts to determine the effect moisture content, soil type and soil density on soil/basement thermodynamics - three areas that to date are not well understood.

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Title	Energy Conservation by Subsurface Construction Heat Transfer Studies in a Large Underground Building. Progress Reports 1, 2 and 3.
Author(s)	Eckert, E; Blight, T.P.; Pfender, E.
Publisher/Date	Department of Mechanical Engineering, University of Minnesota, 1976-1978.
Available from	
Catalogue & Indexing Numbers	NSF/RP-760431
Key Words	
Sector Applicability	Residential Basements

Abstract

These progress reports present the details of the experimental and computer simulation work carried out at Williamson Hall, a large underground building at the University of Minnesota. In this project, the building was backfilled with 5 different types of soil each installed with an extensive grid of thermocouples and moisture sensitive probes. The experimental process and equipment are discussed. A two-dimensional finite difference computer model developed from the data collected is described.

This series of reports presents the results of testing that may lead to a much better understanding of soil/basement thermodynamics. The focus of the experimentation on soil type and moisture content is an area that to date has not been well understood. Unfortunately the computer program developed was unable to take into account changing thermal properties as the moisture content of the soils changed.

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Title	New Methods of Drainage of Basement Walls
Author(s)	Edvardsen, Kunt I.
Publisher/Date	National Research Council, Technical Translation 1603, from Byggmestern, Oslo, 44(18):24-27, 1970
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This is a translation of a study carried out by the Norwegian Building Research Institute on peripheral drainage systems around subgrade basement walls. This study investigates the use of glass wool as a drainage and capillary-disrupting layer against basement walls. Other moisture protection measures as applied in Scandinavia are also discussed briefly.

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Title	New Basement Wall Designs for Below-Grade Living Space
Author(s)	Elmroth, A.; Hoglund, I.
Publisher/Date	National Research Council, Division of Building Research, Technical Translation 1801, from Stockholm, Buggforlaget, 1971.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract	This paper describes research developments in Sweden in which mineral fiber insulation is utilized on the outside of basement walls to provide both a drainage layer and thermal insulation. This technique could have wide application in Canada, both in house basements and other subgrade structures where significant economies may result from the replacement of granular fill by the mineral fibre drainage layer.

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Title	Energy Efficient Housing - A Prairie Approach
Author(s)	Energy Research Development Group, Department of Mechanical Engineering, University of Saskatchewan
Publisher/Date	Prepared for Saskatchewan Mineral Resources, Office of Energy Conservation, and Alberta Energy and Natural Resources, Energy Conservation Branch, October 1980.
Available from	University of Saskatchewan Department of Mechanical Engineering Saskatoon, Saskatchewan
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements
Abstract	Energy conservation measures for new house construction, and the retrofitting of older homes are outlined. Solutions to the problem of air leakage, proper levels of insulation, passive solar gain, and the heating of domestic hot water are presented. Emphasis is on air tightness and the placement of the air-vapour barrier.

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Title	The Saskatchewan Energy-Conserving Demonstration House. Technical Note E 1029-3, The Practical and Economic Arguments for Getting Rid of Basements.
Author(s)	Eyre, D.; Jennings, D.
Publisher/Date	Saskatchewan Research Council, December, 1976
Available from	Saskatchewan Research Council 30 Campus Drive Saskatoon, Saskatchewan S7N 0X1
Catalogue & Indexing Numbers	Technical Note E 1029-3
Key Words	
Sector Applicability	Residential Basements

Abstract

This technical note examines the economics of basements and comparable structures above ground. Construction costs and heat losses through three types of structure are examined: a conventional uninsulated basement; an equivalent wood-framed enclosure above ground; and a basement insulated and finished to the same standard as the enclosure in the second case.

The results indicate that low construction costs for an uninsulated basement are offset by large heat losses and consequently high heating costs. On a total cost basis this first option is substantially more expensive than the other two options. The total cost of the basement can be reduced considerably by insulating it fairly heavily, or by replacing it with an equivalent wood frame storey above ground. Although this latter alternative is more expensive, the authors suggest that given the structural problems of basements in Regina (cracking, heaving, flooding, seepage, etc.) it makes good sense to eliminate the basement and pay a small annual premium for an equivalent wood frame structure above ground.

Title	Air-Vapour Barriers
Author(s)	Eyre, D.; Jennings, D.
Publisher/Date	The New Home Certification Program of Saskatchewan and the Government of Saskatchewan, March 1981, Second Edition
Available from	Saskatchewan Research Council 30 Campus Drive Saskatoon, Saskatchewan S7N 0X1
Catalogue & Indexing Numbers	SRC Publication No. 825-2-E-81
Key Words	
Sector Applicability	Residential Basements

Abstract

The techniques for installing air-vapour barriers presented in this guide were pioneered in the Saskatchewan Conservation House, with futher development by builders on the Energy Showcase Project, a group of 14 energy-efficient houses built in Saskatoon by individual builders. The first section of the report deals with the theory behind the air/vapour barrier and air management. The second section deals with installation of an air/vapour barrier in new and retrofit housing. Problem areas such as the header-floor joist assembly, support beams and corners are discussed in detail, with alternatives presented for each. A comprehensive guide to the installation of air/vapour barriers.

Title	Performance of the Mark IX Steel Basement to 31 March 1973/ Performance of the Mark IX Steel Basement to 31 March 1975
Author(s)	Hamilton, J.J.; Tao, S.S.
Publisher/Date	National Research Council, Division of Building Research, October 1973/November 1975
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	NRC Technical Note 479/NRC Technical Note 595
Key Words	
Sector Applicability	Residential Basements

Abstract

The results of a series of observations and measurements of a steel basement house in Regina. The basement was constructed under the supervision of Dominion Foundries and Steel Company Ltd. (DOFASCO). The foundation walls were instrumented with earth pressure cells, ground movement gauges, wall movement pins and thermocouples. Insulation was applied to the exterior surface of the basement. Problems, results and remedial actions are discussed.

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Title	House Basements on Prairie Clays. Here's How Builders Can Economically Stop Floor Heaving.
Author(s)	Hamilton, J.J.; Handegord, G.O.
Publisher/Date	National Research Council of Canada, Division of Building Research. Published in Canadian Builder, V. 14, No. 9, p. 28, September, 1964.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Report No. HN-20
Key Words	
Sector Applicability	Residential Basements

Abstract

Areas of shifting clay soils in the Canadian prairies often cause extensive damage to basement floors and have resulted in the restricted use of basements as living space in the western provinces. The report details economical methods to prevent heaving of basement floors allowing builders to take advantage of the increasing trend to utilization of basement area as an integral part of a home's living space.

This short technical note provides a good overview of problems that can occur in shifting clay soils and details some remedial action that may be taken.

The use of suspended type basement floors and pile footings are discussed as methods of avoiding certain types of damage from shifting clay soils. Other techniques developed since this article was written (e.g. controlling ground moisture) are understandably not included.

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Title	Crawl Spaces: How to Avoid Trouble with the Foundation
Author(s)	Hansen, A.T.
Publisher/Date	National Research Council of Canada, Division of Building Research. Reprinted from Canadian Builder, Vol. 12, No. 10, October, 1962.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements
Abstract	The paper outlines principles to be followed in the construction of crawl space foundations. It has been found that when not constructed properly, crawl space foundations can be a source of serious problems which can lead to premature deterioration of the entire house. This paper is written as a short technical guide to the builder or designer.

Title	Basement Installation Practice Manual
Author(s)	HUDAC Subcommittee on Foundations and Drainage
Publisher/Date	Housing and Urban Development Association of Canada, October 1980
Available from	HUDAC National Office 15 Toronto Street Toronto, Ontario M5C 2E3
Catalogue & Indexing Numbers	Technical Research Committee Project T79-43
Key Words	
Sector Applicability	Residential Basements

Abstract

A simple and straightforward guide outlining the particulars of good building practice for the placement of footings and foundation walls. Graphics are used throughout the report to ensure a clear understanding of the material. Few technical details are provided. Graphics are used almost exclusively to relay acceptable and unacceptable building practices.

Title	External Insulation of Basement Walls, Phase II Report
Author(s)	HUDAC Task Force on External Insulation of Basement Walls
Publisher/Date	Housing and Urban Development Association of Canada, September 1981
Available from	HUDAC National Office 15 Toronto Street Toronto, Ontario M5C 2E3
Catalogue & Indexing Numbers	Technical Research Committee Project No. T79-44
Key Words	
Sector Applicability	Residential Basements

Abstract

Various aspects of exterior application of insulation to basements are examined including methods of fastening insulation to walls; insulation surface treatment applications; impact resistance and freeze thaw durability of various fibre reinforced insulation surface coatings compared to parging on metal lath. In addition testing was carried out on a cast-in-place concrete basement using two different grades of polystyrene foam insulation and glass fibre insulation of two densities. Methods of fastening parging and flashing the materials were also evaluated in the trial. Relative costs of each application are evaluated.

This is an interim report published as part of a multi-phase research project initiated by the Buildings and Foundations sub-committee of the HUDAC Technical Research Committee. This report can be considered a critical evaluation of external insulation and insulation systems currently available in Canada.

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Title	Principals Applied to an Insulated Masonry Wall
Author(s)	Hutcheon, N.B.
Publisher/Date	National Research Council of Canada, Division of Building Research, February 1964
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Canadian Building Digest No. 50
Key Words	
Sector Applicability	Residential Basements

Abstract

A traditional masonry wall insulated from the inside is compared with a modified design where insulation is applied to the outside. A very basic comparison of the two approaches that, compared to other information currently available, can be considered rather dated.

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Title	Builders Guide to Energy Efficiency in New Housing
Author(s)	I.B.I. Group, Scanada Consultants Ltd. and Hooper and Angus Associates Ltd.
Publisher/Date	HUDAC: HUDAC/Ontario Ministry of Energy Steering Committee
Available from	HUDAC National Office 15 Toronto Street Toronto, Ontario M5C 2E3
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

The aim of this report is to give the typical Canadian homebuilder practical information and guidance in the area of energy conservation in new housing. Information on energy efficient building techniques combined with a consideration of the costs involved makes this a practical guide for builders. All aspects of home energy use have been dealt with and a section on Marketing of Energy Conservation features in new housing has been included. The booklet is an excellent primer for the builder or contractor contemplating energy efficient construction.

Title	Thermal Soil Mechanics
Author(s)	Jumikis, A.R.
Publisher/Date	Rutgers University Press, 1966, 267 pages
Available from	
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This book presents some of the fundamental theories of freezing and thawing soil and the application of these theories to practical thermal problems as they pertain to highway, foundation and soil engineering. The subject as it is presented in the book is thermal soil mechanics including aspects of thermodynamics, heat transfer, moisture migration in soil, strength properties of frozen soil and some aspects of soil mechanics pertaining to the effects of temperature. One of the objects of the book is to point out and analyze some of the problems resulting from freezing and thawing as they apply to thermal stabilization of soil in earthworks and foundations.

Title	Moisture and Freeze-Thaw Effects on Rigid Thermal Insulation
Author(s)	Kapler, Chester W.
Publisher/Date	Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, April, 1974
Available from	
Catalogue & Indexing Numbers	CRREL-MP 1085
Key Words	
Sector Applicability	Residential Basements

Abstract

This report presents data from a limited investigation of some physical properties of various types of rigid foamed plastic thermal insulations. Included in the study were boards of mineral wool, cork, perlite, calcium silicate, urethane, extruded polystyrene and polystyrene beadboard. Long term moisture absorption tests were conducted both in water and after burial in moist soil. Simulated deep submersion tests (1 atmospheric pressure) were made and wetted insulations were subjected to 30 freeze-thaw cycles to observe the effect of these parameters. Strength and flammability characteristics were also evaluated.

This paper is a useful reference documenting the types of degradation insulation in extended and extreme below grade applications. None of the insulating boards tested were found to be completely moisture resistant.

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Title	Frost Action in Porous Systems
Author(s)	Litvan, G.G.
Publisher/Date	Division of Building Research, National Research Council of Canada. Invited paper for presentation at ITBTB-CISC-UNESCO Seminar, "Deterioration and Durability of Concrete and Stone", St. Remy-les-Chevreuse, November 1981.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

In northern latitudes frost action is considered to be the main cause of concrete deterioration. This paper reviews several aspects of the mechanism of frost action. The means by which frost action in concrete can be characterized are discussed. The principal mechanisms by which solids suffer mechanical damage in non-equilibrium freeze/thaw cycles are reviewed and practical recommendations for achieving good resistance to freezing and thawing are made. Direct and indirect testing procedures are summarized.

The document provides a solid techincal explanation of the effect of frost and freeze/thaw cycles on various construction materials. In most cases examples discussed relate more to road and bridge construction than residential basements. Little research has been conducted specifically related to freeze/thaw damage in residential structures.

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Title	Freeze-Thaw Durability of Porous Building Materials
Author(s)	Litvan, G.G.
Publisher/Date	In Durability of Building Materials and Components, ASTM STP 691, P.J. Sereda and G.G. Litvan, Eds. American Society for Testing and Materials, 1980, pp. 455-463.
Available from	National Research Council, Canada Division of Building Research Montreal Road Ottawa, Ontario
Catalogue and Indexing Numbers	
Key Words	
Sector Applicability	
Abstract	This paper presents an account of the studies carried out in the materials section of the Division of Building Research. Water held in the pores of a solid becomes unstable when cooled to temperatures below 0°C. If conditions permit, the water leaves the pores and ice accumulates outside the system. In case of high cooling rate, high degree of saturation, and long diffusion path, the water cannot reach the external surface and solidifies in a glassy, amorphous state. Mechanical damage occurs only in the latter case. This mechanism is not indigenous to any single type of solid, thus it is applicable to cement paste, stone, and brick, and could be used for increasing the durability of porous materials and for improving test procedures.

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Title	The Super Insulated Retrofit Book, A Home Owner's Guide to Energy-Efficient Renovation.
Author(s)	Marshall, B; Argue, R.
Publisher/Date	Renewable Energy in Canada, 1981
Available from	Firefly Books Ltd. 3520 Pharmacy Ave., Unit 1-C Scarborough, Ontario M1W 2T8
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This book looks at the transformation of an average house into a super insulated, airtight house. The principles of insulation, infiltration and air quality control are discussed using alternative approaches for each. This book has been written as an easy to understand guide which the home owner can use when insulating an existing house. The thermal characteristics of seven existing super insulated houses are discussed, outlining the insulation and vapour barrier placement techniques used.

Title	Report on Design and Construction Features of Six Super Energy Efficient Houses in Gillan, Manitoba.
Author(s)	Manitoba Hydro
Publisher/Date	Manitoba Hydro, April 24, 1981
Available from	Manitoba Hydro P.O. Box 815 Winnipeg, Manitoba R3C 2P4
Catalogue and Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This report summarizes the design and construction features of six 103 m^2 houses in Gillan, Manitoba. Significant features include:

- design heat loss of a 4 kW and estimated annual consumption of 6,600 kWh for heating purposes
- annual heating cost of $170 per year compared to $1,100 for similar sized, factory-built houses with basements
- airtight construction reduces the air change rate from 24 per day to as little as 1 per day
- insulation levels of R56 in the ceiling, R40 in walls and R30 for basement walls
- heat exchangers transfer 70% of the heat in exhausted air to the incoming fresh air.

The costs associated with these design and performance features were approximately $5,440 more than a conventional house in Winnipeg.

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Title	Efficient Heating of Buildings Manual
Author(s)	Manitoba Hydro
Publisher/Date	Manitoba Hydro
Available from	Manitoba Hydro P.O. Box 815 Winnipeg, Manitoba R3C 2P4
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This report has been written for the homeowner, primarily those heating their homes with electricity. It deals with several major problem areas in residential construction, these being air/vapour barriers, insulation, air quality control and electric space heating. The placement of the air/vapour barrier and insulation is detailed for all areas of residential construction, with special emphasis placed on trouble spots such as the floor joist-header assembly, and the proper sealing of windows and doors. Methods of controlling humidity and air quality are discussed using structural and internal ventilation, dehumidifiers and air to air heat exchangers. Heat loss calculations are explained so that the homeowner can determine heating requirements and subsequently the heating costs for a home.

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Title	The Impact of Insulation Placement on the Seasonal Heat Loss Through Basement and Earth Sheltered Walls
Author(s)	Meixel, G.D.; Shipp, P.H.; Blight, T.P.
Publisher/Date	Underground Space, Vol. 5, 1980, pp. 41-47.
Available from	American Underground-Space Association 112 Mines and Metallurgy Building University of Minnesota Minneapolis, Minnesota 55455 or Van Nostrand Reinhold Co. 1410 Birchmount Road Scarborough, Ontario M1P 2E7
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract	Based on data collected from an underground building located at the University of Minnesota, a transient, finite difference computer model is used to predict the thermodynamic behaviour of basement and earth sheltered walls. Limitations of the current ASHRAE recommended procedure for assessing heat loss through basement walls (Boileau and Latta) are outlined in light of the new more versatile, though considerably more complicated, computer model. Various insulation strategies are also evaluated in terms of thermal effectiveness and vulnerability to freeze thaw damage. This is a technical paper on field of research of soil mechanics and thermodynamic behaviour.

Title	Thermal Performance of Various Insulations in Below-Earth - Grade Perimeter Application
Author(s)	Ovstaas, G.; Smith, S. et. al.
Publisher/Date	Submitted for presentation at the DOE-ORNL/ASTM C-16 Symposium on Thermal Insulations, Materials, and Systems for Energy Conervation in the '80's.
Available from	U.S. Department of Energy Division of Buildings and Community Systems Washington, D.C. 20545
Catalogue and Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements
Abstract	To better understand the effect of the potentially moist perimeter environment on insulating materials, field studies were carried out in which several materials were installed below grade on the perimeters of two commercial buildings, one in Granville, Ohio, and the other in Sarnia, Ontario. The thermal insulations evaluated were polyurethane, polyisocyanurate, molded bead polystyrene (EPS), and extruded polystyrene rigid foams. Water absorption and thermal transmission data were collected for specimens recovered following earth exposures of 6 and 18 months. Measured thermal transmission data were compared to values calculated from mathematical equations in previously published work. Analysis of measured data indicated that the thermal transmission of several insulations increased significantly as a result of exposure to the perimeter environment.

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Title	Experimental Residential Foundation Designs on Expansive Clay Soils
Author(s)	Poor, A.R.
Publisher/Date	Texas University at Arlington, Construction Research Centre; Department of Housing and Urban Development, Washington, D.C.; Office of the Assistant Secretary for Policy Development and Research, June 1978. 178 pp.
Available from	U.S. Department of Housing and Urban Development Washington, D.C. 20545
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This report examines various methods of reducing foundation damage that might result from construction in expansive clay soils. The activities associated with the design and construction of 11 single-family homes and their behaviour patterns over two years are profiled in relation to the techniques presented.

This paper provides an excellent guide to problems that can occur in expansive clay soils and some unique solutions. One approach involves maintaining high moisture levels in the soil directly around the building with the use of vertical barriers placed in the soil. The rationale of the approach is to maintain a "steady state" moisture level in the soil, thereby eliminating expansive soil movement.

Title	Mark XI Energy Research Project, Design and Construction
Author(s)	Quirouette, R.L.
Publisher/Date	Division of Building Research, National Research Council of Canada, October 1978
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	Building Research Note #131
Key Words	
Sector Applicability	Residential Basements

Abstract

This is one of a series of reports issued by the National Research Council on the Mark XI Energy Research Project. The objective of the ongoing project is to determine the effectiveness of various measures to reduce the energy requirements of single-family homes and to validate a computer program developed to predict the effectiveness of such measures.

While very little in this report deals specifically with the basement areas of the houses, various insulation techniques were used and ongoing results will be useful in predicting performance of various types of insulation in relation to total energy consumption of the house.

Title	Design of Insulated Foundations
Author(s)	Robinski, E.I.; Bespflug, K.E.
Publisher/Date	Journal of Soil Mechanics and Foundations, Division ASCE, Vol. 99, No. SM9, September 1973, pp. 649-667.
Available from	
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper discusses the use of insulation for prevention of frost penetration to the footings and subsequent frost heave. Design principles and soil dynamics are discussed in relation to insulating heated and unheated foundations. A theoretical temperature analysis was conducted using a finite element model and results obtained from a test structure to verify the design process. A general design method for the incorporation of insulation on various type structures is presented.

The paper gives a good review of the principles of foundation insulation for frost protection. However, the finite element model used is limited in its ability to distinguish soil types and climatic conditions that might increase the depth of frost penetration.

Title	Basement Heating Demand Testing in Atlantic and Central Canada
Author(s)	Scanada Consultants Ltd.
Publisher/Date	Prepared for the National Research Council, Division of Building Research, and the Institute of Man and Resources, September, 1978.
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

Heating demand tests were conducted on three homes, each with a different basement insulation approach; basement uninsulated; basement partially insulated; basement wall fully insulated. These three houses are located in Gatineau just north of Ottawa. In addition, one house in Charlottetown, P.E.I. was divided into two test sections with half the basement insulated and the other half partially insulated. Electric heaters were placed strategically through the basements to maintain a uniform temperature. Watt hour meters were placed in line with the heaters to record energy required or actual heat loss.

The purpose of the testing was to help fill a perceived knowledge gap surrounding basement heat losses and the effect of insulation. A major objective of the data collection was to provide a base for further computer modeling.

Title	Mark XI Energy Research Project, Air-Tightness and Air-Infiltration Measurements
Author(s)	Shaw, C.V.; Tamura, A.T.
Publisher/Date	Division of Building Research, National Research Council of Canada, June, 1980
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

Four detached two-storey houses with similar floor plans, and orientation were used to measure air infiltration rates. One house was built using typical construction standards, while the remaining three houses were built with added insulation and a specially applied polyethylene vapour barrier to improve air tightness. All four houses were equipped with an electric furnace and forced air system. In addition one of the upgraded houses has a heat pump unit, and another has an air-to-air solar heating system. Tests were conducted using the pressurization method to determine air infiltration rates.

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Title	Comparison of Annual Heating Loads for Various Basement Wall Insulation Strategies Using Transient and Steady State Models
Author(s)	Shipp, Paul H.; Broderick, Thomas B.
Publisher/Date	Prepared by R&D Division, Owens-Corning Fibreglass Corporation, Technical Centre, Granville, Ohio
Available from	Owens-Corning Fibreglass Corporation Granville, Ohio
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

A one-dimensional steady state model and a two-dimensional transient model were used to determine proper insulation levels and placement for residential basements. Annual basement wall heating loads for both severe and moderate climates were calculated. Interior and exterior basement wall insulation with thermal resistance values ranging from RSI 0 to 3.5, were examined with both full and partial wall coverage. The work concentrated on establishing the comparative differences between the results of the two calculation procedures. Good agreement between the two models was found for estimating seasonal basement wall heat losses and determining optimum insulation levels for various depths down the wall. However, the steady state model developed by Boileau and Latta of the National Research Council was found not to be a good indicator of basement floor heat losses or of the performance of basement structures extending further than 2.5 m into the ground.

This paper evaluates each model in terms of the basement soil components they can most accurately portray. The paper gives good insight into the advantages and limitations of each model.

Title	Thermal Characteristics of a Large Earth Sheltered Building (Parts 1 and 2)	
Author(s)	Shipp, P.H.; Pfender, E.; Blight, T.P.	
Publisher/Date	Pergamon Press Ltd., Underground Space, Vol. 6, pp. 53-64, 1981.	
Available from	Underground Space Centre University of Minnesota or Minneapolis, Minnesota 55455	Van Nostrand Reinhold Co. 1410 Birchmount Road Scarborough, Ontario M1P 2E7
Catalogue & Indexing Numbers		
Key Words		
Sector Applicability	Residential Basements	

Abstract

This paper discusses the experimental design as well as the results of data gathered through physically monitoring the performance of an earth-sheltered building It couples this measurement program with the development of a transient two-dimensional heat transfer model. The experimental data generated at the site were employed to validate the accuracy of the numerical model for a specific test case under known conditions.

The research discussed in these two articles is based on the ongoing monitoring and analysis of the thermal performance of Williamson Hall at the University of Minnesota.

Also discussed are the thermal effects of paved and grassy ground surface cover, as well as of four different soil types examined in this study. The ground surface cover was found to be the most influential element in determining the building's external thermal environment.

Title	Polyurethane Foam as a Thermal Insulation: A Critical Examination
Author(s)	Shirtcliff, C.J.
Publisher/Date	Division of Building Research, National Research Council, November 1978 (Revised)
Available from	National Research Council Division of Building Research Montreal Road Ottawa, Ontario
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper was prepared to aid in understanding polyurethane board and urethane sprays. General characteristics, chemical properties and manufacturing process are described for both insulation types. The techniques used in applying the spray on urethane are outlined, explaining the advantages and disadvantages over other types of insulation. Special problems which occur when applying spray-on urethane under less than optimum weather conditions are detailed.

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Title	Insulation Principles
Author(s)	Technical Response Group for Earth Sheltered Structures
Publisher/Date	Underground Space Centre, University of Minnesota. Prepared for the U.S. Department of Energy, Office of Conservation and Solar Energy
Available from	U.S. Department of Energy Office of Conservation and Solar Energy Washington, D.C. 20545
Catalogue & Indexing Numbers	Earth Sheltered Structures Fact Sheet 05 ORNL/SUB-7849/05
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper outlines the basic principles of insulating below grade structures. Location of insulation, and subsequent wall temperatures, the heat storage capacity of the earth surrounding the structure,the effects of ground moisture on thermal conductivity as well as uniform heat loss achieved through optimum distribution of insulation are discussed.

The paper is written in the form of a fact sheet and provides a good overview for the layperson on below-grade insulation.

Title	Analysis and Measurement of the Thermal Behaviour of the Walls and Surrounding Soil for a Large Underground Building
Author(s)	Shipp, P.H.; Meixel, G.D.; Ramsey, J.W.
Publisher/Date	Underground Space, Vol. 5, No. 2, September/October 1980, pp. 121-125.
Available from	Van Nostrand Reinhold Company 1410 Birchmount Road Scarborough, Ontario M1P 2E7 or American Underground Space Association 112 Mines & Metallurgy Building University of Minnesota Minneapolis, Minnesota
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

In a program designed to ascertain the merits of extending earth sheltered design concepts to a large commercial structure, measurements and analyses are being conducted at the University of Minnesota. From measurements obtained from the 1978 calendar year at an earth sheltered building on campus, the dynamic heat transfer interactions between the building walls and the surrounding soil have been demonstrated and experimental verification has been provided for a transient, finite difference heat transfer computer program developed for the analysis of earth sheltered building envelopes.

Computer generated contour plots detail the influence of the building and the seasonal fluctuations of the soil temperature while graphically illustrating the thermal storage characteristics of the surrounding soil mass.

This paper would be of interest to researchers in the field of soil thermodynamics or those involved in developing computer models or simulations of below-grade heat loss from basements or underground structures.

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Title	Analysis of Transient Heat Loss in Earth Sheltered Structures
Author(s)	Szydlowski, Richard F.; Kuehn, Thomas H.
Publisher/Date	Underground Space, Vol. 5, 1981, pp. 237-246
Available from	Van Nostrand Reinhold Co. 1410 Birchmount Road Scarborough, Ontario M1P 2E7 or American Underground Space Association 112 Mines & Metallurgy Bldg. University of Minnesota Minneapolis, Minn. 55455
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper presents partial test results from experiments conducted at Iowa State University where a two dimensional computer model was used to analyze the thermal impact of varying levels of interior and exterior insulation on conventional basements, earth bermed walls and earth covered structures. Only the results obtained from earth covered structures are provided in this paper. Heat loss and gain through an exterior building envelope vs. location and time of year are given as functions of construction materials, insulation and soil geometry. Temperature distributions within the building envelope material and the surrounding soil are presented in relation to time of year. The cost effectiveness of the insulation applications tested is evaluated.

This is one of a series of papers emanating from the Department of Mechanical Engineering and Engineering Research Institute at Iowa State University. Its focus is on soil thermodynamics and the verification of computer models with field measurement results. This paper would be of primary interest to others involved in computer modeling research.

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Title	Insulation Retrofit of Masonry Basements
Author(s)	Timusk, John
Publisher/Date	Prepared for the Ministry of Municipal Affairs and Housing, Research and Development Section, October 1981.
Available from	Ministry of Municipal Affairs and Housing Research and Development Section 101 Bloor St. West Toronto, Ontario M5S 1P8
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

A review of the various techniques and aspects involved in insulating existing masonry basements. Heat losses from uninsulated basements and common moisture problems are examined and the use of thermal insulation to control these problems is discussed. Various basement types and retrofit options are also discussed.

Typical basement wall, foundation and floor constructions prevalent through Ontario are examined and reviewed in terms of major strengths and weaknesses. Insulating techniques necessarily specific to particular types of construction are noted.

The final chapter of this paper presents a series of heat loss and energy saving calculations for heated and unheated basements for two degrees of climate severity (4000°C dd, 6000°C dd). Savings resulting from a number of retrofit approaches are calculated.

Title	Study of Scandinavian Foundation Insulation Practices
Author(s)	Timusk, John
Publisher/Date	Prepared for the Subcommittee on Foundations and Drainage of the HUDAC Technical Research Committee, Housing and Urban Development Association of Canada, February, 1980.
Available from	HUDAC National Office 15 Toronto Street Toronto, Ontario M5C 2E3
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract	An examination of the Swedish experience in basement and foundation insulation and drainage. Many new applications of various materials developed in Sweden for protecting building structures below ground from frost action and for insulating them to reduce heat loss are detailed. The Swedish Building Code, SBN 75 requirements for basement and crawl space construction are also examined. Advantages and disadvantages of various insulation types are discussed.

Title	Field Study of Moisture Effects on Slab Movements
Author(s)	Tucker, R.L.; Poor, A.R.
Publisher/Date	University of Texas at Austin, ASCE Journal of Geotechnical Engineering Division, Vol. 104, N. 4, April, 1978, pp. 403-414.
Available from	Above
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper documents a series of problems found when investigating 69 poured concrete slabs constructed in areas known to contain expansive clay soils. All slabs were constructed to federal building code standards, yet all experienced problems of some sort. The paper presents a good overview of the types of damage that can occur to slabs located in expansive clay soils.

Title	Solutions to Energy Conservation in Northern Climates
Author(s)	Tymur, E.J.
Publisher/Date	In Proceedings of the National Passive Solar Conference, 3rd, San Jose, California, January 11-13, 1979. Published by the International Solar Energy Society, University of Delaware, Newark, 1979.
Available from	International Solar Energy Society University of Delaware Newark, New Jersey
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

Energy conservation is now being approached through careful consideration of climatic conditions and siting. Mean annual ground temperature in relation to mean annual air temperature; heat loss through conventional basements; artificial and natural (earth) insulative properties; passive and active solar heating systems; and design in response to immediate site conditions are discussed as design elements. These principles have been applied in the design of the Tymura solar-heated residence located in northwestern Ontario. Demonstrating a combination of passive and active space and water heating and partially underground construction, the completed residence is calculated to save up to 90% of its annual heating requirements.

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Title	**Earth Sheltered Housing Design; Guidelines, Examples and References**	
Author(s)	The Underground Space Centre, University of Minnesota	
Publisher/Date	Van Nostrand Reinhold	
Available from	Van Nostrand Reinhold 1410 Birchmount Road Scarborough, Ontario M1P 2E7	or Underground Space Centre University of Minnesota Minneapolis, Minnesota 55455
Catalogue and Indexing Numbers		
Key Words		
Sector Applicability	Residential Basements	

Abstract

This book discusses all aspects of earth sheltered buildings. The first section deals with site planning, architectural and structural design, water proofing and insulation characteristics in earth sheltered houses. Thermal characteristics and energy use are discussed in detail with comparisons to conventional housing. The aesthetics and economic feasibility of alternative earth sheltered designs are considered. The second section of the study gives examples of existing earth sheltered houses, designed for both cold and warm climates. Three major aspects of existing houses are discussed; architectural design, site planning considerations, and energy use projections.

Title	Earth Sheltered Structures, Fact Sheet 05, Insulation Principles
Author(s)	U.S. Department of Energy, Office of Conservation and Solar Energy
Publisher/Date	U.S. Department of Energy, Office of Conservation and Solar Energy, May 1981.
Available from	U.S. Department of Energy Office of Conservation and Solar Energy Washington, D.C. 20545
Catalogue & Indexing Numbers	ORNL/SUB 7849/05
Key Words	
Sector Applicability	Residential Basements

Abstract

This fact sheet discusses the basic premises governing the insulation of building surfaces in contact with the ground. The effect of insulation on thermal performance is examined for the reduction of heat flow and retention of heat and temperature stability. Major parameters that affect the optimum quantity of insulation are discussed and include: climate, internal heat, ground moisture and ease of adding insulation. Optimum distribution of insulation around the building envelope will depend on a compromise between insulating for minimum heat loss or maximum cooling.

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Title	Mathematical Modelling and Computer Simulations of Insulating Systems in Below Grade Applications
Author(s)	Wang, F.S.
Publisher/Date	ASHRAE/DOE Conference on Thermal Performance of Exterior Envelopes of Buildings, December 3-5, Orlando, Fla.
Available from	U.S. Department of Energy Division of Buildings and Community Systems Washington, D.C. 20545
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

This paper presents theoretical results of finite element heat transfer modelling of several below grade building configurations. This model is verified by comparing results for simple heat conduction problems involving freezing and thawing. It is then used to determine heat loss through below grade basement walls with various internal and external insulation placements. The effects of different construction techniques are also evaluated.

This paper is devoted primarily to the theoretical development of models to predict the thermodynamic performance of below grade installations and applications of insulation. It is a research oriented paper and of little direct use to the builder or designer.

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Title	Energy and the Builder: Floors and Foundations
Author(s)	
Publisher/Date	Professional Builder, Aug. 74, V.39, N.9, pp. 112(5)
Available from	Manitoba Hydro P.O. Box 815 Winnipeg, Manitoba R3C 2P4
Catalogue & Indexing Numbers	
Key Words	
Sector Applicability	Residential Basements

Abstract

Instructions are given for the insulation of crawl spaces, basements, slab foundations, and floors to save heat. Three types of insulation for this purpose are: glass fibre batt for crawl spaces, floors and basement walls; polystyrene foam board for under slabs; and vermiculite masonry fill for filling cores of concrete block. Financial aspects of insulation are also considered.

This article is written in an easily readable style and oriented specifically to the home construction industry. It provides a very straightforward approach and deals with proven insulation methods.

POOR

QUALITY

ORIGINAL